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PROCEEDINGS OF THE SOCIETY OF ARTS

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PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-FOURTH YEAR, 1905-1906

BOSTON, March 8, 1906.

THE 620th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, Institute of Technology, on Thursday evening, March 8, 1906, at eight o'clock. Seventy-eight persons were present. Dr. William H. Walker presided.

The minutes of the previous meeting were read and approved. There being no routine business, the chairman presented the speaker of the evening, Mr. Henry G. Kittredge, editor of the *Textile American*, who addressed the Society on the subject of "Shoddy, or the History of a Woolen Rag."[1]

Mr. Kittredge gave an historical account of the development of the shoddy industry, and described what is meant by shoddy and its method of manufacture from rags. He showed its economic value as a substitute for new wool, stating that not sufficient wool is grown

[1] Below, pp. 65

to meet the demands for woolen fabrics. The manufacture of mungo was also briefly described.

The lecture was illustrated by stereopticon views showing the process of manufacture and the machinery employed.

The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

BOSTON, March 22, 1906.

The 621st meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, Massachusetts Institute of Technology, on March 22, 1906, at eight o'clock. Professor Augustus H. Gill presided, and 135 persons were present. The minutes of the previous meeting were read and approved.

The chairman then introduced Professor William H. Walker, who addressed the Society on "The Chemistry of Cellulose as Applied to Textile Fibers, Mercerized Cotton, Artificial Silk, and Horse Hair." The speaker described the work which led to the application of the process to mercerization on a practical scale, and also outlined the chemistry of cellulose. The difference between nitro-cellulose and the derivative substances was shown by experiment, as was also some of the physical properties of the cellulose derivatives. The use of artificial silk and artificial horse hair in the manufacture of fabrics, laces, hats, etc., was described and demonstrated by a very complete collection of samples. The machinery used in the manufacture of these products was shown by means of lantern slides.

Some discussion followed, and the chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

BOSTON, April 12, 1906.

The 622d regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, Massachusetts Institute of Technology, on Thursday evening, April 12, 1906, at eight o'clock. Mr. George W. Blodgett, chairman of the Executive Committee, presided. Attendance, seventy-eight.

The minutes of the previous meeting were read and approved. Mr. Joseph W. Phelan was elected an Associate Member of the Society.

The speaker of the evening was Mr. Ernest Harold Baynes, who addressed the Society on "The American Bison, Our Grandest Native Animal." Mr. Baynes gave an idea of the numbers and range of this animal in the past and the methods which were adopted by the whites and Indians for its destruction, and which have resulted in its almost complete extermination. He said that the number of these animals existing is but a few hundreds, and these are located in two or three groups, the largest of which is at Corbin Park in New Hampshire. The methods for assisting its propagation were described, and a strong appeal for its preservation by national aid and through private individuals was made by the speaker.

The lecture was illustrated by a number of colored lantern slides showing the characteristics of the animal at different stages in its development. An especially interesting series was one which showed a couple of buffalo calves which had been broken to harness by the speaker. The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

BOSTON, April 26, 1906.

The 623d regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, Institute of Technology, on Thursday evening, April 26, 1906, at eight o'clock. Mr. James P. Munroe presided. Fifty-five persons were present.

There being no routine business the chairman introduced Mr. H. F. J. Porter, of New York, who addressed the Society on "The Rationale of the Industrial Betterment Movement."

Mr. Porter said that the move to secure better surroundings for the working people by improving the sanitary conditions and supplying recreation rooms, gymnasia, etc., is not based entirely upon charity, but in most instances is a good business investment for the employer because of the increased efficiency of the employees.

He described the improvements instituted by several companies, notably the National Cash Register Company of Dayton, Ohio, and

showed by a series of pictures the conditions prevailing in several works before and after the industrial betterment movement had gone into effect.

After some discussion on the subject the chairman expressed the thanks of the Society to the speaker for his excellent talk, and the meeting adjourned.

SAMUEL C. PRESCOTT, *Secretary.*

SHODDY, OR THE HISTORY OF A WOOLEN RAG

By HENRY G. KITTREDGE

Read March 8, 1906

NOTHING marks more completely the industrial progress and efficiency of a nation and people than the utilization of products that have been thrown aside in the manufacture of other products, that can be turned to a useful purpose in meeting the desires or necessities of man.

Nearly all great municipalities have systems for collecting rubbish within their precincts with one of the objects, however secondary it may be, of turning it to some commercial account. For example, the rubbish found in the streets of Boston is collected in carts by scavengers and carried to a general refuse station, where it is sorted on movable tables, by Italians, it may be. At the refuse station, each sorter has his particular kind of waste to pick out as it moves in front of him, to be thrown into a pile or bin by his side, and afterwards pressed into bales. The clean, high grade paper sorts are used in the manufacture of paper again, and the lower grades are used in making different qualities of paper cardboards. This is the shoddy of the paper manufacturer. Ropes and burlaps are used to make yarn for cheap burlaps. We have here another kind of shoddy. Old boots and shoes find their way to the glue shop. Tin cans are thrown into a furnace and the solder is saved for further use as solder, while the melted tin is cast into molds for window sash weights. Old iron hoops, etc., are remelted into scrap iron ingots. Bottles are sold at so much a barrel and again made use of for various purposes. Cotton rags are picked out for paper stock, while the woolen rags are sold to junk dealers, who sort them over for the shoddy manufacturer. Thus it will be seen that scarcely anything is allowed to go to absolute waste, and never a word is raised against this practice in industrial economy, except as it may relate to woolen rags for their subsequent conversion into a wool substitute. We find in this municipal practice of collecting rubbish and assorting it into kinds one of the beginnings of the wool shoddy industry.

The word shoddy is, without doubt, a modern factory term, and this view of it is taken by the Century Dictionary, which regards it as "a dialectic form (diminutive or extension) of dialect 'shode,' literally 'shedding,' separation, shoddy being originally made of flue or fluff 'shed' or thrown off in the process of weaving, rejected threads, etc."

A cognate word to shoddy is mungo, a term, however, peculiar to the parlance of English rather than of American mills. The Century Dictionary gives an alleged but unverified etymology of this word as coming from "mung," "mong," "mang," meaning a mixture, as in

FIG. 1.—INTERIOR OF A REFUSE STATION
Sorting street rubbish on a movable table

mangcorn. The woolen trade, however, gives it an outlandish derivation, as a corruption of the expression "must go," from a circumstance which should be alluded to especially, as it has a traditional relationship to the word "shoddy," and is indelibly associated with the origin of the shoddy industry, although entirely confined to Yorkshire (England) patois. It is related, upon very uncertain authority, that at the time this shredded or picked up stuff was invented a dealer possessed a quantity of it, and some doubt was expressed as to its salability, when he declared that "it mun go," meaning that it must go. There are variations of this story.

The inventor or originator of shoddy as a material to work with wool for spinning is unknown; and whoever may receive the credit holds the distinction largely upon the acquiescence of those who cannot show evidence to the contrary. Samuel Jubb says that the presumption is in favor of Benjamin Law as the person who first produced it, at Batley, in 1813 or prior thereto; but it appears that several persons began the making of shoddy at about this time.

There is a claim for Brighouse as having had in operation rag machines prior to any in Batley, but in qualification of this claim it is said that these machines were for picking thrums, hard worsted waste, and the like, and not for producing rag shoddy.

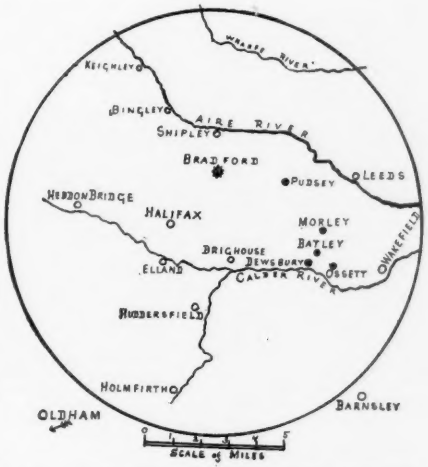


FIG. 2. — SHODDY MANUFACTURING DISTRICT OF ENGLAND

Solid black dots show the principal centres of manufacture of shoddy

It has been intimated at times that George Parr, an early manufacturer of mungo, was entitled to the credit of appropriating rag wool to the manufacture of woolen cloth. This intimation, however, must be regarded as more or less gratuitous, as it has been disowned by his descendants even as late as 1880, when his son Benjamin is reported to have said that he never knew of any rival claim to that of Mr. Law having been set up by his father of being the first to manufacture shoddy cloth.

The rag grinding machine in the early part of the nineteenth century was a most primitive affair. We are told that the first one for pulling rags to pieces or converting them into fibres was made by Joseph Gibson, of Cleckheaton, at the suggestion of Joseph Jubb, a leading business man of Batley, who had conceived such a machine from one he had seen running at Brighouse. The next machine was constructed by a Mr. Archer, of Ossett — a name that afterwards became identified with the early history of the industry in the United States.

As soon as it became known that woolen fabrics for clothing were being made with an admixture of shoddy with pure wool and sold in the market as consisting of pure wool, denunciations of the most pronounced kind were hurled against their manufacture. The London *Times* and other newspapers in the kingdom anathematized this species of wool manufacture as militating against the morals and health of the people. No doubt the shoddy cloth of that time was miserable stuff and deserved all the bad epithets which it received, as the material out of which it was then made was quite different from what it is today.

Up to 1834 the only class of stock that was available for converting into shoddy was technically known as "softs," as flannels, stockings, etc., or such as was knit or loosely woven. All closely woven or felted rags had been cut into flocks or thrown away as so much rubbish and allowed to rot till they became fit for manure. Until then the rag-picker had not been mechanically improved so as to permit it to shred this kind of closely textured material. By this time, however, the machine had been so improved in structural details as to enable it to pick into a fibrous condition hard felted cloth, as broadcloth, kerseys, etc. This suggested to George Parr the commercial advantage of utilizing this stock in the same way as was being done with stockings, etc., for preparing it for manufacture into goods. In the carrying out of this idea, Mr. Parr is credited with being the inventor of mungo, which the prepared material was christened, from the incident already alluded to, which, however, may not have occurred till later. The advent of mungo as a coördinate material with rag wool made from soft stock established an important era in the history of the woolen industry in England, and soon led to significant events in the United States that gave to our manufacturers an intimacy with the utility of this stuff for mixing with wool. The material obtained from soft rags was totally unsuitable for fabrics as pilot cloth, beavers, or any kind of heavily felted or face-finished goods; hence its opportunities for usefulness were limited. That obtained from hard rags was finer fibred and better adapted for this class of goods, and for this reason was of more beneficial consequences to the woolen trade.

It has already been observed that one of the first rag pulling or shoddy machines built was made by a Mr. Archer, of Ossett, probably about 1810. In 1831, Richard Ardict, living in the adjoining town of Dewsbury — a friend and neighbor of this Mr. Archer or of the Archer family — believing that the United States offered business opportunities

that were not apparent in England, bought of George Archer, of Ossett, son of the Archer alluded to, a ragpicker, as it was then called, boxed it up, and shipped it for New York as a rice threshing machine, intending to follow it himself on the next vessel; but before the vessel carrying the machine had been fairly on its way the British government was informed of the artifice and attempt to circumvent the act of Parliament prohibiting the export of machinery and tools.

In consequence of this violation of the statute, Mr. Ardict was

FIG. 3.—GEORGE PARR'S SHODDY MILL, BATLEY, ENGLAND
In operation in 1834, and many years prior thereto

arrested; but after he had been incarcerated for some time he was given his liberty upon the payment of a fine of twenty-five pounds sterling. He had, however, accomplished his purpose in getting his machine out of the country, and immediately sailed for New York, where he found his machine had already arrived safely. He moved it to Marlborough, Ulster County, New York, and there started the first shoddy mill in this country in what was known as the Hepworth Mill. He carried on the business there for many years and then moved the plant to Esopus, New York.

Soon after the departure of Richard Ardict from Yorkshire for the United States, George Archer began to contemplate quite seriously the plan of doing likewise. He completed all necessary arrangements for this purpose and started for New York in 1836, his family following three years after. Profiting by the experience of his friend Ardict, and "knowing a trick worth two of that," instead of exporting a machine contrary to the statutes of the kingdom he simply stored away in his baggage a complete set of drawings for the various machines used for the manufacture of woolen goods, including those for the construction of a ragpicker.

Shortly after Mr. Archer's arrival he formed a copartnership with a Mr. Bailey and a Mr. Ogden, under the firm name of Archer, Bailey and Ogden, and located at Little Falls, New Jersey. Mr. Archer's part of the business was to build the machinery, while his partners looked after the manufacture of shoddy and cloth. This firm continued in business for several years, when Mr. Archer withdrew and moved to Paterson, New Jersey, where he engaged, alone, in the building of shoddy machinery. After being in Paterson for a number of years, he moved to Tuckahoe, New York, from there to Cohoes, New York, and finally settled in Marlborough, New York, where he continued to make shoddy machinery till the time of his death, in 1875, at the age of seventy-two.

In connection with the beginning of the shoddy industry in the United States, as established by Richard Ardict and George Archer, should be mentioned the early enterprise of A. G. Dewey, Quechee, Vermont, the most distinguished of the pioneers in this line of manufacture. Mr. Dewey commenced the manufacture of shoddy and of goods in which this material was used, in 1841, at Quechee, and successfully conducted it to the time of his death in 1886, when it passed into the hands of his sons. The shoddy picker used by Mr. Dewey was an invention of Reuben Daniels, of Woodstock, Vermont. This invention was wholly original with Mr. Daniels, who knew nothing of the machines of Mr. Archer. It is safe to say that his machine was different from the English make, but in what particulars there is nothing in existence by which this can be even partially or moderately determined. He was a large and successful builder of woolen machinery, and his shoddy machines were probably designed from the picker he was then building for working wool, with the cylinder armed on its periphery with hooks of claws. The picker, it is known, reduced the

rags to very small pieces and shreds, which were then run through another machine, called a "grinder," which had a double cylinder with under workers arranged in a long box containing running water, which carried the stock through.

No patent of a ragpicker similar to the kind now in use is on record in the patent office at Washington. There was a patent taken out by O. Griswold in 1837 for a waste picking machine that suggests the possibility of its use for picking rags, though in the specifications no direct reference is made to shoddy by name. A patent was given to J. Bailey in 1849 for a waste picker that might have answered for tearing up rags, and may have been designed for this purpose, as reference is made in the specifications to its adaptability for the manufacture of shoddy.

FIG. 4.—SHODDY MILL OF A. G. DEWEY, QUECHEE, VT.

At the right of the new brick building. The oldest shoddy mill in the United States now in existence. Operated since 1841

It was not many years ago when most of the woolen rags that were collected in the United States for manufacture into shoddy were procured from the housewife by the tin peddler and his one horse cart, in return for which he bartered certain household wares, and afterwards disposed of his rags to the rag dealer. In those days rags and other similar household savings were worth something, or at least enough to warrant the exercise of this domestic economy, but now the price received is of scarcely sufficient inducement to pay for the trouble of saving.

The tin peddler has given or is rapidly giving way to the junk collector with his sack or team, whose occupation is largely passing into the hands of those of foreign birth, especially the Russian Jews. This class of people may be seen in the neighborhood of all the large cities in the North, with a sack in the hand or thrown over the shoulder, going from house to house for whatever rags they can obtain, to be afterwards disposed of to the junk dealer.

The junk dealer sorts his various purchases into grades, usually five in number — as old cloth and garments; soft woolens, as knit stuffs, flannels, etc.; satinets and linseys; carpets; and cotton.

The junk dealer's customer is the rag dealer, who sometimes conducts a large business, for which purpose he occupies extensive

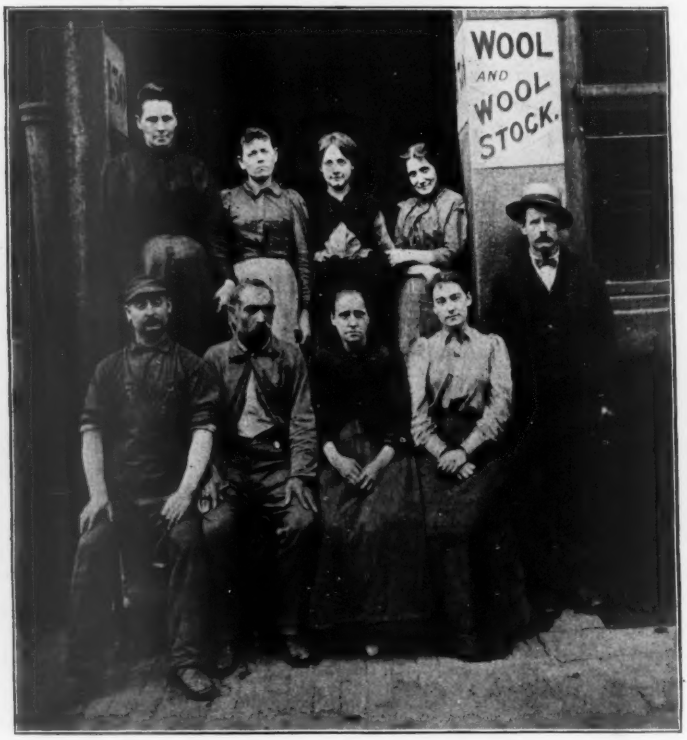


FIG. 5. — GROUP OF RAG SORTERS

quarters and employs a large number of employees, made up mostly from the foreign element of our population. The rag dealer goes over his old cloth sorts and makes new sorts of them according to quality and color, or whatever it is desired to obtain to meet the peculiar demands of trade. The old garments are treated likewise after all the linings, etc., have been removed.

New rags, or new clips, as they are called, consisting of tailors'

trimmings or clippings made in the cutting rooms of ready-made clothing houses and elsewhere, are purchased direct by the rag dealers and not through junk dealers.

After the rags have been sorted by the dealer, each kind is baled by itself and securely bound with wire or hoops for transportation.

When the rags are received at the shoddy factory they are again looked over or more carefully sorted to meet more thoroughly the par-

FIG. 6.—RAG SORTING IN A DEALER'S LOFT

ticular wants of customers, more in respect to color than to quality, though the latter may be considered, especially as to whether the rags are old or new, all wool or partly cotton, and, if the latter, thrown aside for the "extract" process. Much depends on the use to which the shoddy is to be put.

There are several kinds of processes through which woolen rags pass into shoddy, dependent on the nature of the rags and what is wanted. If the rags have cotton threads in them they are submitted to the "extract" process.

FIG. 7. — CUTTING ROOM IN A TAILORING SHOP

Excellent sanitary arrangements. Where "new clip" rags are obtained for the nicest class of shoddy

FIG. 8. — A BAKING ROOM FOR CARBONIZING RAGS

Rags are seen on tables. Temperature kept at 200° and above for about eight hours

FIG. 9. — PARTLY CARBONIZED CLOTH

The warp of this cloth is wool, the weft cotton. The lower end has been carbonized and the cotton destroyed, leaving the wool intact

The "extract" process is simply a method of eliminating or extracting vegetable matter that may be associated with wool in rags. The process is better called carbonizing by which the vegetable substance, as cotton, is eliminated by acid and heat, which converts the cellulose into hydrocellulose, which is removed by mechanical means.

All methods of drying are practically the same, in that the rags are exposed to a heat of 200 or more degrees for about eight hours. The acid and heat burn the cotton to a powder that is easily shaken out in an ordinary dusting machine.

After the carbonized rags have been dusted they are put into a washing machine and washed with water with some alkalinity to neutralize the acid remaining in the rags. The rags are then redried for the ordinary processes employed in the manufacture of all-wool shoddy.

None of the extract processes came to be employed to any great extent, in the United States, at least, till well after 1870, because of the prejudice against them as injuriously affecting the felting properties

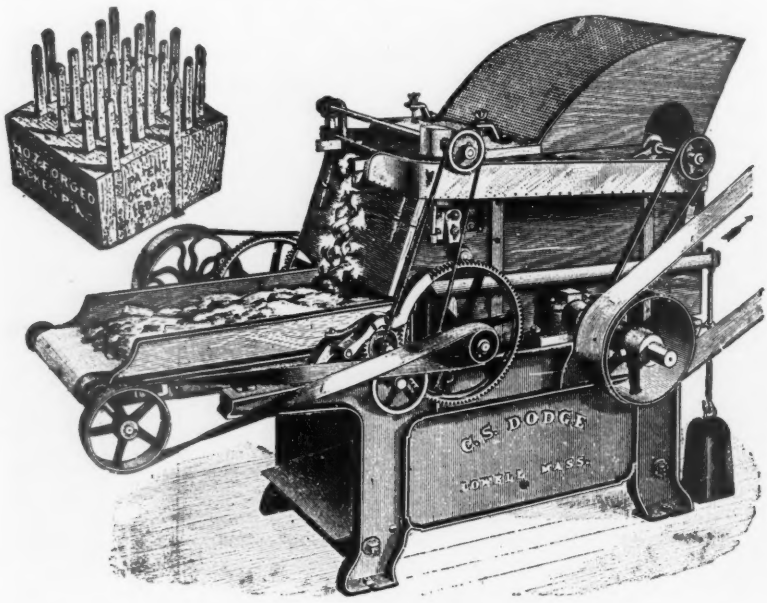


FIG. 10. — A MODERN SHODDY PICKER

Portion of a peripheral wooden lag, magnified, is shown with the picker pins, or teeth, inserted

of the wool fibres, due very largely to the imperfect knowledge of the proper methods that should be pursued in the joint application of acid, heat, and neutralizing alkalies.

The shoddy picker which is employed for manipulating every kind and condition of rags, whether for extract, mungo, or what not, is a very simple and inexpensive piece of mechanism, consisting of a large, heavy cylinder, in the peripheral wooden lags of which are securely driven a large number of closely set straight steel pins or teeth, by which

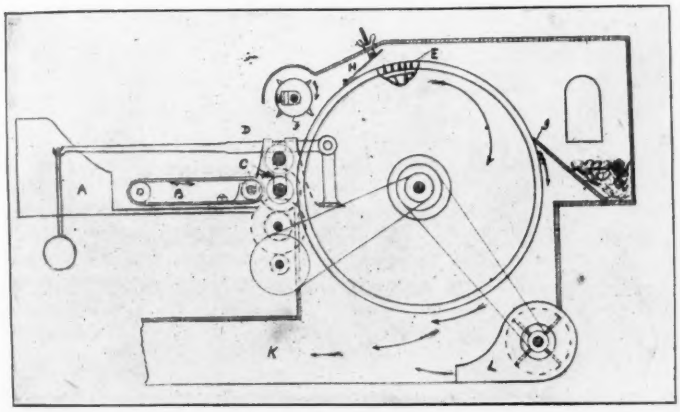


FIG. 11.—SECTIONAL VIEW OF A MODERN RAG PICKING MACHINE
Style used in England

A. Rag box.
B. Movable feed table.
C. Feed rollers.
D. Lever with weight.
E. Main cylinder showing teeth.
F. Bitter.
H. Knife board.
I. Bit board.
K. Flue.
L. Fan.

FIG. 12.—MEN FEEDING TWO SHODDY PICKING MACHINES
Rags are seen on the floor and on the machines

the picking of the stock is effected as they revolve in close contact with two small steel feed rolls that slowly deliver the material to be operated on.

Shoddy is oftentimes used in the manufacture of goods just as it comes from the picker, but when a nice preparation of the stock is required it is passed through a carding machine or an ordinary wool card.

After leaving the picker or the carding machine, as the case may be, the shoddy is packed in bags for transportation to the consumer. When waste yarn or soft, very loosely woven, or knit, goods are converted into shoddy, the picker and the carding machine may be done away with, and the Garnett machine alone employed. This is a comparatively new machine invented by an Englishman by the name of Garnett. It is usually built with three main cylinders, with a large number of smaller cylinders, all provided with steel teeth, working in conjunction with each other so as to tear the stock to pieces and convert it to a fibrous condition ready to be used the same as wool.

Akin to shoddy are flocks or powdered wool made from cut or ground up woolen rags. Rag flocks are first prepared on a machine, which cuts the rags into small pieces or strips in good condition to be fed into the flock cutter. In the manufacture of woolens, flocks are employed for increasing the weight of the goods with a material much less in cost than either wool or shoddy, and in this respect are as much a substitute for wool as shoddy; but instead of being mixed and spun with wool like the latter in the ordinary processes of manufacture, they are incorporated into the fabric after it leaves the loom, during the process of felting or fulling; and so firmly do they become embedded in the texture of the goods that it is impossible or very difficult to dislodge them, and to this extent permits the manufacture of a compact, heavy, and durable cloth at a comparatively small cost.

In the process of shredding rags it is reasonable to suppose that more or less injury will be done to the fibres, but the damage done is very much less than may be thought.

However great the consumption of shoddy, flocks, etc., may be, it does not begin to meet the deficiency in the supply of wool, which has to be supplemented quite as much, if not more, by cotton. If I should place the world's consumption of shoddy at 300,000,000 pounds — an extreme amount, probably — it would be nearly one-fourth the consumption of clean wool. The consumption of shoddy in the United States

may be taken at about 80,000,000 pounds, or little more than one-half that in Great Britain. In our woolen mills alone — not including those for worsteds, carpets, felts, and knit goods — at the time the 1900 census was taken, for the manufacture of cloths, overcoatings, tweeds, flannels, cassimeres, satinets, etc., there were used about 120,000,000 pounds of clean wool and other animal fibres, and about 67,000,000 pounds of shoddy, or altogether 187,000,000 pounds, nearly 36 per cent. of which was shoddy. Our woolen goods, therefore, as a whole, carried a good

FIG. 13. — A DOUBLE CARDING MACHINE
Used when a nice preparation of shoddy is required

proportion of shoddy at that time, with probably little change since. In addition to this amount might be added about 60,000,000 pounds of cotton, showing still more the immense dependence of the woolen industry upon other materials from the animal and vegetable kingdoms than pure wool; and this dependence is not one of choice, but of necessity.

There exists among a great many people a strong and unreasonable prejudice against shoddy as a material in the manufacture of woolen goods. As now made, especially that which has gone through the

extracting or carbonizing process to which most rags are subjected, nothing can be much less deleterious to bodily health. The acid, heat, washing, etc., to which woolen rags are exposed are more than sufficient to kill every germ of disease and to leave the material in a condition less to be apprehended for infectious distempers than pure wool. No matter whence woolen rags may come, before they are converted into shoddy they are made absolutely pure by the extracting or carbonizing treatment. The rags gathered from the scums of communities are made as unsullied as those obtained from the most immaculate households before they are permitted to be used for shoddy. There is much more to be feared from the handling of cotton rags that are collected from all the foul places of the world, many of which are fouler than

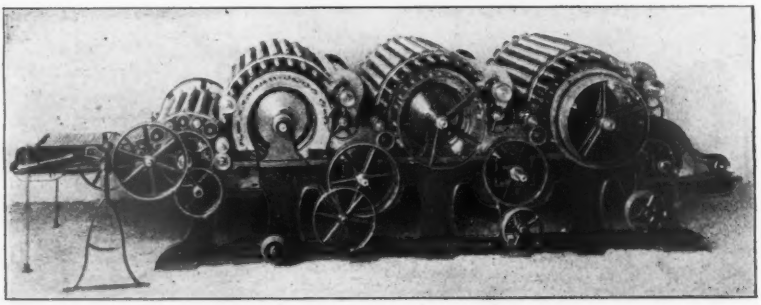


FIG. 14.—A GARNETT MACHINE
For converting yarn, or soft, loosely woven, or knitted goods into shoddy

the foulest whence are obtained woolen rags. Yet these cotton rags are not considered unfit to go into the manufacture of the finest paper for a *de luxe* edition of some choice book, and in this state of existence are little thought of as containing anything detrimental to human health, as they do not. But they are no cleaner or freer from disease germs than the wool shoddy that now goes into the cloth that is made up into garments for our wear. In both instances the chemical treatment to which the rags are submitted is sufficient to kill every vestige of disease that may be present from any cause. The only thing that can be said against shoddy conformable to the fact is that it has a short and perhaps defective fibre, and consequently does not make a high grade cloth. But this objection may be made against pure or unmanufactured wool, much of which has no longer fibre and makes no more desirable cloth other than is secured in a possibly better physical condition of fibre.

The danger of disease from woolen rags is no greater, if as great, than from some classes of wool. In this respect, woolen rags have never been legislated against by commercial bodies and governments as some kinds of wool have been. Nothing like the terrible disease

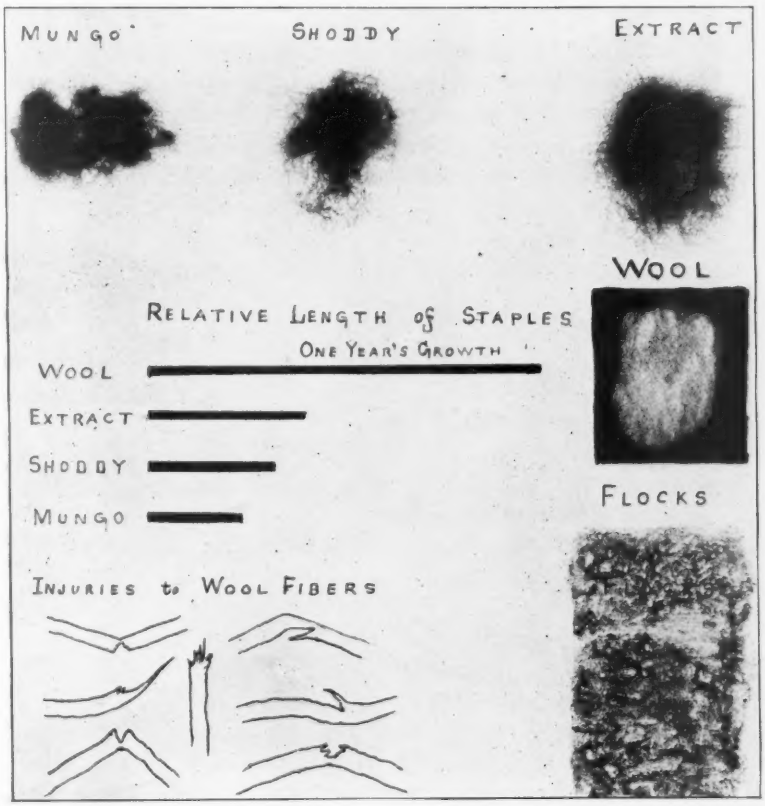


FIG. 15. — PHOTOGRAPHS OF MUNGO, SHODDY, EXTRACT, AND WOOL (CALIFORNIA FALL CLIP, FIVE MONTHS' GROWTH), REDUCED ABOUT ONE-QUARTER

Injured fibres magnified. The injuries done to the fibres are exaggerated, and represent only extreme instances

of anthrax that comes from contact with certain wools and hairs is derived from the handling of woolen rags.

Shoddy is a legitimate article for use in the manufacture of wool, as thoroughly so as the fibre in its original condition from the animal's

back, and is no more a sham or imposture than the real article for which it is substituted; not a particle more than the silver plating on spoons and forks in imitation of sterling silver.

Shoddy is one of the greatest blessings that has been vouchsafed to the wool manufacturing industry. It contributes 300,000,000 pounds of wool fibre every year toward keeping the industry within its legitimate realm, and that much free from dependence on cotton, and it supplies a material for serviceable and well appearing cloth that can be manufactured at a comparatively low cost for the great masses of the people.

Instead of being cursed it should be eulogized.

TECHNICAL CHEMISTRY IN TECHNICAL SCHOOLS

By HENRY P. TALBOT

THE position which applied science, as distinct from pure science, occupies in the curriculum of a technical school is often exaggerated in the thoughts of those whose interest may be, from one or another cause, drawn to such institutions. The primary purpose of these schools is to educate their students with direct reference to their usefulness as technicians, and it would seem quite logical that the dominant ideas throughout the teaching of the sciences should be those which relate to their applications to the useful arts, and that, as a consequence, a commercial spirit might well invade the work of the lecture room and laboratory. Indeed, this conception seems occasionally to prevail even in the minds of those no farther removed than the teachers of science in our colleges, for it is not an unknown experience to interview a would-be student who comes with a message from a fellow-instructor in the more academic field which indicates with rather disturbing clearness that he, too, has assumed that the technical school aims to train rather than educate its students. It is not strange, then, that nearly every fortnight brings requests from individuals who have little to guide them beyond their preconceived notions of a technical school, for the opportunity which they believe to be offered to be equipped in the course of a few weeks, or even a few days, for life work as a chemist, frequently in some highly specialized field, and the same thing is doubtless true of other sciences.

It may not, then, be untimely to indicate the extent to which an effort may be made, on the one hand, to educate rather than merely to train the student for his life work in his chosen field of science, and on the other hand how, in the case of chemistry at least, most excellent use can be, and is made of the technology of the science, even from the very beginning of the various courses of instruction.

In planning a scheme of instruction in chemistry for students in a technical school, two serious problems must be confronted at the start,

namely, the vastness of the science and the varying capacity, aptitude, and enthusiasm on the part of the students to be taught. One has but to glance through the subdivisions of chemistry in such a publication as the *Chemisches Centralblatt* to realize the utter futility of any attempt to do more than to gain a general notion of the scope of many of the specialized branches; and when it is remembered that no man today can be an efficient chemist who is not also something of a physicist, mathematician, and linguist, it becomes evident that within the limit of four years a scientific education must be mainly confined to those general phases of the science which are common to most or all of its subdivisions.

The chemistry which is taught in the first year in a technical school must usually be presented to a class which is made up of students who do not expect to follow the subject in later years, others who take professional courses in which chemical subjects play a more or less important part, and still others who expect to follow chemistry in some of its branches as a profession. The first of these groups must obtain their entire conception of chemical science from such a course, and the other two must gain from it a foundation upon which to build in subsequent years. The proportion of the student's time which may properly be claimed for the subject is not large, and the instruction to be adequate must be carefully chosen and should be in the hands of teachers of maturity and experience, both on the lecture room and laboratory sides. Such a course is fundamentally one of instruction in the principles of the science. But principles are abstract conceptions, and they are dry and tedious for the man whose interest is not primarily in this particular science unless they are associated with specific facts, and best with facts that have to do with affairs within the student's personal experience, or those which can easily be shown to lie in the path of probable future experience. It is exactly at this point that the mature man of science can call to his assistance his own professional work to great advantage, and this is often the more effective if the illustration is taken from his contact with technical interests; but this does not at all involve an introduction of what,may be termed the dollars and cents point of view or any degradation of instruction. The architect, for example, will the more quickly interest himself in the law of constant proportions or the metallurgy of iron if he is led to understand that these matters are vital to the stability of his structural work; the mechanical or civil engineer will grasp the theory of solutions the more

readily if he is able to see that it applies directly to the treatment of boiler waters; and the mining engineer or the chemist will find in the brief account of the solution of some technical problem from the instructor's professional practice an inspiration for extra reading and study.

With the differentiation of courses which usually occurs at the end of the first year in the technical schools, the problem is partially simplified by the elimination of those students for whom chemical instruction ceases at that time. There remain students in such professional courses as mining engineering, sanitary engineering, physics, biology, and geology, beside those in chemistry or chemical engineering.

Analytical chemistry, as the ultimate measure of accomplishment or the means of control of chemical processes, is an essential for all of these groups of students. Here, again, the judicious teacher will include something of technical chemistry to lend vitality to the work. The substances placed in the hands of the student for examination and report will be chosen from the open market in preference to purely artificial mixtures, and the history of the substance will be told when it is issued for analysis, or upon its completion. The methods of analysis chosen will not, however, necessarily be identical with those used in technical laboratories, but will rather be selected because they represent general types of analytical procedure with which every analyst should be acquainted, and the student will be led to regard them as such and to criticise them and his own work intelligently, in the light of reading and study; that is, the effort will be made to develop a thoughtful, self-reliant worker rather than a man with a knowledge of particular methods. On the other hand, technical methods will not be avoided when they also represent desirable types, nor will the instructor fail to emphasize the requirements of the technical laboratory with reference to speed and accuracy; and "rapid methods" will receive due attention if the time at his disposal is reasonably adequate for this as well as the inculcation of habits of accuracy and self-criticism. The latter must, however, receive first consideration, and no greater mistake can be made in the education of a student as an analyst than to overemphasize the acquisition of methods as such, especially many of the technical methods. Every director of a works laboratory will have his own methods adapted to his own line of materials, and the student who has been taught to meet an analytical problem thoughtfully should have no difficulty in quickly learning these, or, if thrown upon his own resources, in devising methods of his own.

It is sometimes contended that the graduate, fresh from the instructional laboratory, when he enters the works laboratory is slow in his work; that he is overcritical, and too little disposed to cut corners when such abridgment is desirable. But it will surely be granted that these are less serious faults than overhaste and heedlessness, and that a course of instruction in which fundamental principles and underlying reasons are associated with the acquisition of analytical technique offers the surest foundation for successful practice. It is such a course that the technical schools should give and, for the most part, are giving.

The applications of chemistry in technical practice may be summoned to the assistance of the instructor in organic chemistry in much the same way that has already been noted in the case of inorganic chemistry, but to a rather less extent. There is little danger that this course will acquire a commercial taint, as it deals largely with the principles underlying the classification and behavior of the vast collection of carbon compounds, the subject being treated essentially from that standpoint.

Much the same statement may be made regarding physical or theoretical chemistry, which deals with the fundamental principles of the science. But here again much may be gained, without incongruity or sacrifice of dignity, by frequently pointing out to the student a concrete technical application of what appears as an abstract principle.

The technical school, then, like the college, should teach science fundamentally from a somewhat abstract standpoint, for the problems of applied science demand for their solution, before all else, a knowledge of principles. Students are all too prone to feel that only those phases of the science the applications of which they can appreciate are worthy of their serious attention — a notion which no institution can afford to foster by giving to such general subjects as inorganic, organic, theoretical, or analytical chemistry a more directly commercial trend than has been outlined above. On the other hand, it is essential that students who are to make the application of chemical science their life work should be afforded opportunities to learn something of the general methods employed and of the practical problems to be met with in that field, and to this end it is necessary to offer separate instruction in what is usually designated as "industrial chemistry," in the course of which these matters are frankly treated. The scope of a proper scheme of instruction in industrial chemistry may well be a theme for much discussion, and the final word may not soon be said.

It is obvious that no course in industrial chemistry will of itself make an industrial chemist of any student who has not absorbed "pure" chemistry from other courses, as well as a proper share of mechanics, mathematics, and physics. The function of the instruction in "applied" chemistry as distinguished from "pure" chemistry must be to broaden his horizon by permitting him to see beyond the test tubes, beakers, and porcelain dishes, so necessary in the analytical or organic laboratories, to the tubs, vats, filter-presses, or acid chambers of the works; and to realize, even though it be imperfectly, the new factors, such as use of power and cost of materials and labor, which enter into the technical problems, but are not taken account of in the ordinary problems of the student analyst.

The course naturally divides itself into the lecture or recitation-room instruction, and that in the laboratory. These parts should be coördinated, and the former should deal with typical operations common to many processes, such as filtration, lixiviation, evaporation, etc., followed by the descriptions of the process of manufacture of important products. Details should be given with moderation and after thoughtful selection, and the descriptive side should be accompanied by, or perhaps subordinated to, a careful exposition of underlying reasons, and whenever it is possible, full emphasis should be laid upon the useful applications of the principles of chemistry, mechanics, or physics. It is evident that such a presentation of the subject can only be adequately made by one who has had some vital contact with chemical industry through actual service or frequent visits, and the man who combines with such an experience the natural aptitudes of a teacher is already widely sought and is likely to be still more generally desired by educational institutions throughout the country.

The aim of such instruction obviously cannot be to impart a knowledge of the manufacture of any one product extending to minute details, which would probably be of little or no value to any single member of a group of students. It may, however, be of great service in affording a classification of processes and a general conception of the methods employed to handle materials of various sorts, or to secure certain ends.

The value of the classroom instruction is greatly enhanced by trips to industrial establishments taken under the guidance of the instructors (short trips during the school year, with longer journeys for such as are able to participate in the summer). Here, too, the breadth of expe-

rience of the instructor is an important factor, for the benefit derived increases in geometrical ratio with the effectiveness of the preliminary talks designed to render the observations of the student acute and intelligent. In this connection one can hardly express too much appreciation of the courtesies extended by the manufacturing interests in making such visits possible, as they must often become sources of greater or less inconvenience. Of their real benefit to those who participate in them, no one who has had opportunity to observe results will probably raise a doubt. They are particularly helpful in bringing to the attention of the student the need and usefulness of breadth of knowledge both within and without his professional work.

But a question was long ago raised whether it is necessary to depend entirely on these visits to established plants to emphasize the precepts of the classroom instruction in industrial chemistry; that is, to what extent laboratory instruction in industrial chemistry is possible or advantageous in educational institutions. The conclusions reached are varied. Some will express the conviction that nothing of the sort should be attempted; others will approve of courses which are essentially those of inorganic preparations on a somewhat large scale; still others will maintain courses which aim to illustrate, through the preparation of a few products on a moderate scale, the nature of the factors entering into the problems of the industrial chemist and the kind of difficulties which he has to meet and overcome; and there is the further possibility of the establishment of a plant upon a semi-industrial scale, which should be run continuously and in which the student should serve a brief apprenticeship, devoting himself, for this space of time, entirely to this work.

Experience seems clearly to justify the establishment of laboratory courses in this subject, but they should not be those in which the preparation of certain materials is the principal end sought. To be advantageous they should be so conducted as to bring to the student a realization of the meaning of what has been called the "economics of chemistry." Such a course has been fully described by Dr. W. H. Walker in *The Technology Review*, Volume VI, page 163. The experiments "are selected not so much for their intrinsic merit or relative importance as for the ease with which they are adapted to laboratory conditions and the exactness with which the several factors making up their final efficiency may be controlled." Some of these factors are: cost of materials, cost of reagents, mechanical difficulties

to be overcome and types of apparatus and kinds of material available, the control of reactions involved, the use of scientific tables in technical work, the use of instruments of technical accuracy little known in other lines of work, the value of waste or wash liquors and their utilization, the purity of the product, and the presentation of a systematic report. Such factors as the cost of labor or power, the depreciation of plant, or interest on investment are not, of course, directly subject to determination in the laboratory; but these are taken up and discussed in conference. The work is further arranged in such a way that several students will work simultaneously upon a given problem, a single factor being altered by each, the final results being discussed in conference, and in all this the spirit of investigation is carefully fostered.

In a course of this character no claim is made that actual industrial conditions are duplicated; it is the industrial trend of the course which constitutes its value, and the things which it suggests and the points which it raises for discussion and conference are its vital features. Such suggestions are avowedly based upon work which is upon a very small scale in comparison with an industrial plant, and many of the problems of the latter can only be dimly realized by the student. The other suggestion, that a plant, composed of units from a limited number of large chemical plants for the production of such products as muriatic or nitric acids or electrolytic bleach liquor, should be established and operated by students, contemplates a closer approach to working conditions, and would possess unquestionable advantages. Against these must, however, be placed the very considerable cost of housing, establishment, and maintenance of a plant of this sort, the present (although not insuperable) difficulties in adapting the work in such a plant to the schedules of the college year, and the fact that this would, after all, be but another stage in the progress toward actual industrial conditions without having attained them. Just where the balance between these considerations would lie is a question which deserves the serious thought of those entrusted with the charge of chemical instruction.

The term "industrial chemist" has become closely synonymous with that of "chemical engineer" in recent times, and the chemical engineer is defined as one versed in chemical science, who also possesses such a knowledge of mechanics and engineering that he is capable of transforming the chemical reaction of the test tube or beaker into a plant capable of turning out some product of the reaction on a technical scale

and at a profit. It is undeniably true that this is the general type of man sought for today, and in his education time must be found for a fundamental training in mathematics, mechanism, mechanics, and steam engineering, as well as in the principles and practice of chemistry — a task to which five years rather than four need to be devoted. This breadth of education is absolutely demanded in positions of superintendence and wide responsibility, and it is highly desirable even in the less prominent positions, but its acquisition necessarily lessens the time which can be devoted to the strictly chemical development of the student, and it is to be hoped that in the not too distant future there will also be an increasing call for men to take positions in technical establishments the preparation for which will involve an even more thorough chemical training. Research laboratories are apparently growing in favor in the industrial field, and the establishment of endowed laboratories for technical chemical research in connection with technical schools may be one of the welcome developments of the coming years.

The education of the technical chemist or chemical engineer must, then, be far from being dominated by the technical or commercial point of view. A knowledge of "pure" science, whether chemical, physical, or mechanical, must always be his mainstay rather than his experience with applied science. Added to this, he must have the ability to think clearly and independently, not merely to follow, but to lead. With this at his command and with ability to get on with his fellowmen, his success is reasonably assured.

THE RELATION BETWEEN TECHNICAL EDUCATION AND INDUSTRIAL PROGRESS[1]

By ROBERT H. RICHARDS

All clear thinkers agree that there *is* a close relation between technical education and industrial progress, but that to be effective the education must be of the right kind.

Industrial progress in the last fifty years has consisted in seeing an opportunity and in finding a way to make the most of it.

About 1870 in the United States, the opening up of new territory called for iron for railroads and for agricultural tools. The best iron blast furnaces of the United States were then making something like 25 tons of pig iron a day. They were in the hands of ironmasters who learned their trade at the furnaces and did their work as they had been taught by their predecessors. Any suggestion of change from the adopted method drew out the reply, "That was tried in my grandfather's time and proved to be a failure." The furnace method had been at a standstill for years, and improvements were apparently impossible. At about this time the American scientific schools began turning out their graduates, and the Americans who had obtained similar training abroad returned. These men brought in a new leaven, and the resulting increase in the work of a furnace is represented by the following figures:

Charcoal Iron Furnace

Date.	Hearth.	Height.	Capacity.
1870	2 feet 6 inches	39 feet	10 tons each 24 hours
1890	6 feet 7 inches	60 feet	130 tons each 24 hours
1904	8 feet 6 inches	70 feet	160 tons each 24 hours

[1] Read before the Mining Society of Nova Scotia at Halifax, March 22, 1906.

ANTHRACITE IRON FURNACE

Date.	Hearth.	Height.	Capacity.
1870	10 feet 10 inches	40 feet	25 tons each 24 hours
1890	11 feet 4 inches	73 feet 11 inches	100 tons each 24 hours
1904	14 feet	100 feet	465 tons each 24 hours

COKE IRON FURNACE

Date.	Hearth.	Height.	Capacity.
1897	10 feet 6 inches	75 feet	207 tons each 24 hours
1904	12 feet 6 inches	85 feet	321 tons low grade ores
1904	15 feet 4 inches	100 feet	600 tons high grade ores

LEAD BLAST FURNACE

Date.	Hearth.	Height.	Capacity.
1870	2 feet square	12 feet	12 tons
1880	36 x 100 inches	14 feet	60 tons
1890	42 x 140 inches	. .	120 tons
1900	48 x 164 inches	. .	160 tons

COPPER REVERBERATORY FURNACE

Date.	Hearth and height.	Capacity.
1878	15 feet 0 inches x 9 feet 8 inches	12 tons
1887	21 feet 2 inches x 12 feet 8 inches	24 tons
1894	35 feet x 16 feet	50 tons
1904	50 feet x 32 feet	90 tons
1906	112 feet x 19 feet	350 tons

COPPER BLAST FURNACE

Date.	Hearth.	Height.	Capacity.
1881	28 x 28 inches	8 feet	35 tons
1883	48 inches diameter	10 feet	60 tons
1885	48 x 121 inches	8 feet	100 tons
1900	56 x 180 inches	18 feet	400 tons
1904	56 x 180 inches	18 feet	500 tons
1906	56 x 612 inches	18 feet	1,600 tons

The same wonderful progress is true of the Bessemer process. When it was first introduced into the United States, about 1868, two converters could work five charges of five tons each, 25 tons in all, each day. Now, through the improvements brought in by the introduction of scientific methods, two converters can make 900 to 1000 tons of steel a day. Names prominent in this advance are Holley, Wood, Schwab, and others.

The story of the copper furnaces has been the same. The reverberatory of 1878 had a hearth 9 x 15 feet and worked 12 tons in twenty-four hours. The Argo, Colorado, reverberatory now has a hearth 19 x 112 feet and works 350 tons.

The lead furnaces of 1870 were 24 inches square in section and smelted 12 tons in twenty-four hours. Now they have cross sections 48 x 164 inches and smelt 160 tons a day.

Such extraordinary development as this came, not without resistance from conservatism, as the direct effect of the application of science and the scientifically trained mind to the subject in question. It is true, self-made men have been present in this wonderful procession, have done their share in bringing on the advance, and have done it nobly, but they walked side by side with the technically educated men and had their trained chemists. They read and studied the current literature.

Having noted a few main facts of the development along certain lines, let us look for a moment at some of the obstacles which had to be overcome.

First we come to the classical college as it then was. The speaker's own experience may be cited: He had been at a classical preparatory

school until two years older than the normal age. He worked industriously and seriously, but made little progress. The work was always uphill, and required great effort to keep his attention. At the last moment a change was made. Instead of going to a classical college he went to a scientific school, where he was immediately fascinated by the study of scientific phenomena of physics, chemistry, geology, engineering. Instead of having to drag himself to his books he could not keep away from them; instead of reading books of ancient history and mythology to please his teacher he now tried experiments to demonstrate laws of nature for himself, and read the authors at first to see if his demonstrations accorded with theirs, but afterward to see if they agreed with him.

The right to question even what is written in books is not only the right but the duty of every scientific man.

The speaker's experience has been that men brought up on the classics have their best field in literature, law, theology, and politics, where oratory and logic of persuasion count most, and that those who go from this training into mining, metallurgy, and manufacturing have a certain bondage to authority to overcome. But when men of this class are emancipated from the bondage to authority they furnish the finest examples of intellectual ability.

The men who have been graduated from a scientific school have been taught to observe, to record, to collate, to conclude — to observe the phenomena as they are occurring, to record what they see as it really is, without a bias, to collate the results, correcting instrumental and personal errors and tabulating results, so as to *conclude* wisely what is to be expected from the premises. Men who have been taught by this method have learned how difficult it is to see and how important it is to keep an open mind in order that wisdom may have a chance to act. The modern scientific man is most courageous in experimenting; his imagination has been highly cultivated; nothing daunts him; he annihilates time and space, and does in a year the work of a former generation. He knows that, while he may be disappointed again and again, if he can only find the true cause and sequence of facts he can then press the button and the results will follow.

"Why not let opportunity make the man?" is asked. Dr. Drown has answered: "A technical school is a device to save time. Man's days are still three-score years and ten, but now he crowds as much into them as Methuselah did into his 969 years."

Mr. Chamberlain, of England, says: "I do not think it is necessary for me to say anything as to the urgency and necessity of scientific training. . . . It is not too much to say that the existence of this country (England) as the great commercial nation depends upon it."

While the classically educated men have been the mainstay of society for a long time on the lines where they are strong, they did not bring about the modern industrial progress or help in it until the modern engineering schools led the way. Since that time the colleges have come into line, each with its engineering and chemical departments.

The Eye and the Mind

The importance of hand work in the school for demonstrating the fact that when we look at a thing we do not see it all has been proved beyond all doubt. In the speaker's own experience he constantly hears from some student, "I have tried that machine for concentrating this ore, and it is a failure." The teacher's reply is, "Are you sure that you tried the experiment rightly and saw everything that was going on?" A repetition of the test frequently brings a reversal of the decision. The speaker has known many cases where improvements have been turned down simply because the eye and the mind of the experimenter have not been sufficiently trained to grasp the bearings of what was being done.

The effect of the practical school training upon an engineer is well shown in the following instance: The engineer referred to sent a drawing of an intricate forging to a firm in one of the Southern states. The manager sent it back, saying, "The piece cannot be made." The engineer, thinking that the other had misunderstood the drawing, made a wooden model of the exact shape he wished the finished piece to have. This he carried over to the works in person. The manager said, "Not only are we unable to make this piece, but the man does not live who can make it." The engineer asked, "May I have the use of a forge?" This was granted, and all the expert blacksmiths of the place gathered around him to see this greenhorn of an amateur make a fool of himself. He worked through his task logically step by step, and brought out the finished piece just like the wooden model. He was then asked by the manager, "Did you ever see one made?" "No." "Did you ever see one like it?" "No." "How did you know one could be made, and where were you taught to make

it?' "I was taught the principles on which everything is made at the Massachusetts Institute of Technology in Boston." At this reply the manager said, "I don't believe a word of it."

The above is a very good illustration of the different ways in which the two classes of minds look at things. The trained scientific mind is ready to undertake anything. The rule of thumb man will go as far as he sees, but his imagination fails him. The former can mentally analyze and reconstruct, while the latter can do only what he has been taught.

The use of the shop for the development of skill and imagination is well illustrated in this way: The teacher of forging shows the pupil in successive lessons how to draw a piece of iron, how to make a piece round or square, how to punch an eye, how to make a weld, how to make an offset and a rivet. He then asks his pupil to make a pair of blacksmith's tongs. The answer comes: "But I can't. I never did such a thing in my life." The teacher is inexorable, and the pupil begins. He finds to his surprise that the task before him is simply a grouping together of a series of steps, each of which he has already mastered. The first tongs a good student makes will compare well with the work of an average country blacksmith who has had years of experience.

The change from the rule of thumb man to the scientifically trained man has not been without its difficulties, most of which had their origin in the jealousy of the former and the inexperience of the latter.

It is interesting to note the devices to which the young scientist has to resort in order to overcome the barrier of conservatism. For example, an engineer, seeing great waste of good material taking place at an iron blast furnace, at first asked permission of the ironmaster to save it by putting it in the furnace. He was met by the stock remark, "My grandfather tried that and proved it a failure." The young man then tried the opposite tack. Analyses of the usual ore and also of the said waste material were placed side by side on the manager's desk. This was done repeatedly and as an apparent coincidence, until the manager noticed one day that the alleged waste material was richer than the ore, and he said, "I believe that stuff would make iron, after all," and ordered that the trial be made. As soon as it became the act of the manager and he received the credit for it the saving was all right and the thing to be done. When the young

scientist found that his diplomacy had triumphed in the first case he tried it again on another line. In this way, time and again, advances were made, until the real source of improvement was recognized by the capitalists, and the old, conservative manager gave place to the young, progressive one. But this was only after the young scientist had gained sufficient experience to make it safe.

An exceedingly interesting case of the breaking down of conservatism shielded behind barriers of religion and nationality, as well as international distrust, occurred to a young American who taught a school in India. He recognized early that the teaching of tool work must be more forceful for his purpose than book work, but he saw also that to introduce foreign tools would excite antagonism at once. He therefore set the Hindu young men at work designing a tool to cut wood. A little careful, unnoticed guiding on the part of the teacher brought the young designer to the modern approved form, but the tool was the Hindu's own design. He had not only made it, but he had created the idea. The credit was his. The barrier thus broken soon fell, and progress was rapid.

Many instances might be given of the lagging of industrial progress because advantage of technical knowledge was not taken. For example, in geological work the speaker once knew a young school man who, at a mining summer school, was taken by a local home-taught mineralogist and geologist at the eastern slope of the Rocky Mountains in Colorado to visit certain outcrops around the vertical coal seam being worked there. The young graduate quickly reconstructed from the fragments the probable geological structure of the place, including a syncline with axis north and south and the coal mine on the western slope, combined with a horizontal bedding extending indefinitely eastward. From these scattered fragments he predicted that the coal seam would be found 200 feet deep, more or less, in the eastern plain, in undisturbed and therefore better condition than in the coal mine then being worked. He reported his conclusion to the manager and to other prominent men. They all turned it down as the dream of a schoolboy or the notion of a "scientific cuss."

Twenty-five years later it was found that many square miles of coal did underlie those plains. In this instance not only the business man and coal manager could not see it, but the home-taught geologist had not thought of it until his attention was called to it.

In another instance a young man went to Maryland to survey coal

property in a syncline valley. He noticed that where the central river bottom and the branches cut below the coal the following of outcrop was easy and the survey simple, but the outside croppings were blind. To run these in his survey he designed a geometrical rule by which he ran long distances of outcrop, coming out at the next visible sign near enough to plot the lines. The young country surveyor who helped him was greatly taken with this plan, and laid it up in his mind.

Years afterward the latter met the former and said: "Some New York men came down here and wanted to buy coal land outside our lines. I told them that there was no coal there and that they would be disappointed. They persisted, made their purchase, put down borings, but found no coal." Here the business man refused the advice of the scientist, and suffered in consequence.

Pure logic often forms a bulwark behind which conservatism can rest; that is, pure logic builds upon facts a structure of argument that, if certain things are known, certain other things will follow. But if the supposed facts turn out to be incorrect, then the whole structure falls. The difference between the logician and the scientist is that the logician assumes his premise to be correct and the scientist doubts everything. The comment comes from Edison, Whitney, and others in words to this effect: "In questions of industrial progress no man living knows *all* the facts, and so the questions of success or failure cannot be answered by logic until not only every probable and possible thing has been tried, but everv impossible thing also."

As previously pointed out, technical education is acquired not only in the school, but in contact with fellow-workers.

In the United States the interchange of visits and cordial comparing of notes have always been the rule. Some change in the way of shutting out visitors is now coming in, which is to be regretted. An instructive example along this line came in a Pittsburg meeting of the American Institute of Mining Engineers. On one of the excursions two old friends were conversing, and one said: "I always thought my works were the most advanced of any. In consequence I have never asked others to visit me and have not visited them. I now find that I am at the tail end of the procession."

Not only are men blind and conservative, but nations are still slower to adopt new ideas.

Sir Norman Lockyer says: "Britain in the middle of the last

century was certainly the country which gained most by the advent of science, for she was then in full possession of those material gifts of nature — coal and iron — the combined winning and utilization of which, in the production of machinery and in other ways, soon made her the richest country in the world, 'the seat and throne of invention and manufacture,' as Mr. Carnegie has called her."

The beginning of the decline of English supremacy in manufactures has been said to date from the time when A. W. Hofman left England to go to Germany because a few thousand pounds needed to pay him and equip his laboratories were not forthcoming. The government officers who should have appreciated the situation and his value to the kingdom did not, and as a result his wonderful inspiration and storehouse of experience was taken from England and given to Germany.

In his presidential address before the British Association in 1903 Lockyer also said: —

"Our position as a nation, our success as merchants, are in peril chiefly — dealing with preventable causes — because of our lack of completely efficient universities and our neglect of research.

"We now know, from what has occurred in other states, that if our ministers had been more wise and our universities more numerous and efficient, our *mental resources* would have been developed by improvements in educational method, by the introduction of science into schools, and, more important than all the rest, by the teaching of science by experiment, observation, and research, and not from books. It is because this was not done that we have fallen behind other nations in properly applying science to industry, so that our applications in that direction are relatively less important than they were. But this is by no means all. We have lacked the strengthening of the national life produced by fostering the scientific spirit among all classes and along all lines of the nation's activity; many of the responsible authorities know little and care less about science; we have not learned that it is the duty of a state to organize its forces as carefully for peace as for war; that universities and other teaching centres are as important as battleships or big battalions; are, in fact, essential parts of a modern state's machinery, and as such to be equally aided and as efficiently organized to secure its future well-being.

"Suppose we were to set about putting our educational house in order, so as to secure a higher quality and greater quantity of brain

power; it would not be the first time in history that this has been done. Both Prussia, after Jena, and France, after Sedan, acted on the view:

> When land is gone and money spent,
> Then learning is most excellent.

"After Jena, which left Prussia a 'bleeding and lacerated mass,' the king and his wise counselors, among them men who had gained knowledge from Kant, determined, as they put it, 'to supply the loss of territory by intellectual effort.'

"After Sedan, a battle, as Moltke tells us, 'won by the schoolmaster,' France made even more strenuous efforts. The old University of France, with its 'academies' in various places, was replaced by fifteen independent universities, in all of which are faculties of letters, science, law, and medicine.

"But even more wonderful than these is the 'intellectual effort' made by Japan, not after a war, but to prepare for one.

"The question is, Shall we wait for a disaster and then imitate Prussia and France, or shall we follow Japan and thoroughly prepare by 'intellectual effort' for the industrial struggle which lies before us?"

The Effect of Technical Education in the United States

In the United States the most interesting aspect of industrial progress is the atmosphere of alertness that prevails, in contrast to the conservatism of the old country. It is so contagious that it affects all who come. This is well illustrated in the case of a Welsh copper metallurgist who came at an early date to the Rocky Mountains, and soon absorbed progressive ideas. Just after he had rebuilt his copper furnace so that its capacity should be increased from 40 tons to 80 tons he received a letter from a friend in the old country, saying: "We are contemplating increasing the capacity of our furnace from five tons to six tons. Do you think it would be safe to make the change?" The former replied, "After careful consideration of your question for a week I think that it would be safe."

How comes it that there is this alertness and adaptability? It is partly in the air. The speaker believes that the modern schools of the class of the Massachusetts Institute of Technology have had a large share in this. They take the boy from the high school and, before he has lost his youthful enthusiasm and his quickness in learn-

ing, equip him with principles, blaze out his path for him, and turn him out well started along the road to become an engineer. The fact that he begins his practical work in the world before he has passed the age of greatest acquisitiveness is a very strong point in favor of a course involving only four years from the high school.

Sir Norman Lockyer asserts that "in the United States the most successful students in the higher teaching centres are snapped up the moment they have finished their course of training, and put in charge of large concerns."

(The speaker differs with the last part of this quotation. He certainly hopes that none of his pupils will be rushed ahead at quite that speed.)

In Britain, on the other hand, apprentices who can pay high premiums are too often preferred to those who are well educated, and the old rule of thumb processes are preferred to new developments.

It has repeatedly been noted that in England the training of skilled workmen and foremen is carried to a high degree of excellence and the training of engineers and leaders has been neglected; but that the exact opposite is the case in the United States.

At this stage of industrial development everybody believes in education of the right kind as a help, and the natural question is, "What is the right kind?" The speaker thinks that kind represented by the Massachusetts Institute of Technology.

The United States technological schools, engineering departments of universities, and the state mining schools all give courses in the various lines of engineering and chemistry. Capital for this training has been furnished liberally by individuals, and high tuition has been paid by students who see the immediate profit coming from the investment. The great progress in the United States dates from their beginnings.

In Germany the Technische Hochschule of Charlottenburg fits men for the various engineering professions and for chemistry. A recent catalogue showed 3,000 students, the length of the course about four years, the number of graduates eighty.

The students of the Technische Hochschule are allowed, to a limited extent, to participate in the tests of the testing station at Lichterfelde in the capacity of assistants. But as Lichterfelde is one of the suburbs of Berlin and Charlottenburg another they are not suited for close association with each other.

The other German states also have Technische Hochschulen.

In regard to the English schools, according to quotations from Lockyer, the technological schools have not reached the standard of those of Germany or the United States. The speaker has not been able to corroborate or refute this statement on account of the brief time allowed to prepare this address.

Modern education is no longer a log with Mark Hopkins at one end and a boy at the other. It is no longer Greek roots and Latin tenses. The education we have referred to deals with the principles of chemistry, physics, electricity, mechanics, metallurgy, and ore dressing as underlying industrial progress.

To elucidate the principles laboratories are needed, supplied with the requisite apparatus.

The laboratories of ore dressing with which the speaker is connected are supplied with small machines with which to test the concentration of ores. The small size diminishes the first cost, the running cost, and the exhaustion of students from handling heavy weights, and yet the apparatus is large enough to decide all the important questions of designing a mill process. They can tell when crushing to 16 m.m. 8, 4, 2, or 1 m.m. in size, whether the slimes saved by the coarse crushing more than offset the better and cleaner concentration with fine crushing, and many other important points.

The question is often asked, "Should professors do expert work?" The speaker thinks, "By all means, yes." Their teaching is greatly strengthened by having a little connection with the world of action. It helps to keep them awake and up to times in the problems of the day. They should not, however, allow it to rob the students of time to which they have a right. Moreover, the outside practitioners would be very nervous if the school men, with the added prestige coming from their position in the school, should appear in serious competition and take away much of the business.

Should research laboratories be established? The arguments are strongly in favor of them. In the United States research laboratories are being installed in connection with schools and are helped by the Carnegie Institution.

The large corporations are realizing the importance of research laboratories. The General Electric Company and the Westinghouse Company both have laboratories covering acres of floor space. The former has from twenty to thirty assistants constantly on new work,

so great is the field for industrial improvement and consequent profit to the company.

At Berlin, Germany, the Government Testing Works (Versuchsanstalt) at Lichterfelde-West, have the following departments:

Testing metals for tension, compression, torsion, elasticity, conductivity, heat-treatment, corrosion, etc.

Testing building materials, such as brick, mortar, cement, concrete, for strength and durability, density and absorption.

Testing paper for strength, absorption, and filtering power, together with examination by the microscope and other means.

Testing metals by metallography — that is, etching, polishing, microphotography — determining the eutectic curves of metals, and other tests.

Testing substances by chemical analysis. There is a complete chemical laboratory for chemical analysis of metals, of materials used in manufacturing, and of gases.

Testing oils for fluidity, flash point, ignition point, refractivity, and for sulphur by vacuum distillation, fractional distillation, or other means.

When samples are tested without charge the results are published in the annual report for the benefit of the public. Those that are paid for, on the other hand, are treated as confidential.

There are also in Berlin an establishment for standard weights and measures, which is of great benefit to manufacturers and users for purposes of comparison, and the Berlin Physikalische Reichs-Anstalt, an institution for research in chemistry and physics.

The other German states have testing stations of the same general character as that of Berlin, Prussia, but they are not developed to quite the same extent.

In the United States the Watertown Arsenal has a department for testing, in charge of the Ordnance Department of the United States Army. There are three varieties of work done at this station:

1. Testing for the Ordnance Department of metals and materials for guns, etc.

2. If the above work is not pressing general tests of engineering materials are undertaken. The results of these are published.

3. Work for individuals for a fee. The results of these tests are considered confidential.

The United States Geological Survey is doing work on the testing of structural materials and fuels. During the summer of 1905 it

undertook also the testing of black sand, in which the speaker took part. From the sea and river sand, as well as the sand from hydraulicking and dredging for gold, minerals of commercial value were obtained, namely, magnetite, chromite, garnet, monazite, and zircon. In some cases they will prove to be of economic importance.

The Bureau of Forestry of the Department of Agriculture is making timber tests.

Many schools and colleges do some testing of materials of engineering and of ores and of chemical products for individuals independently of the government.

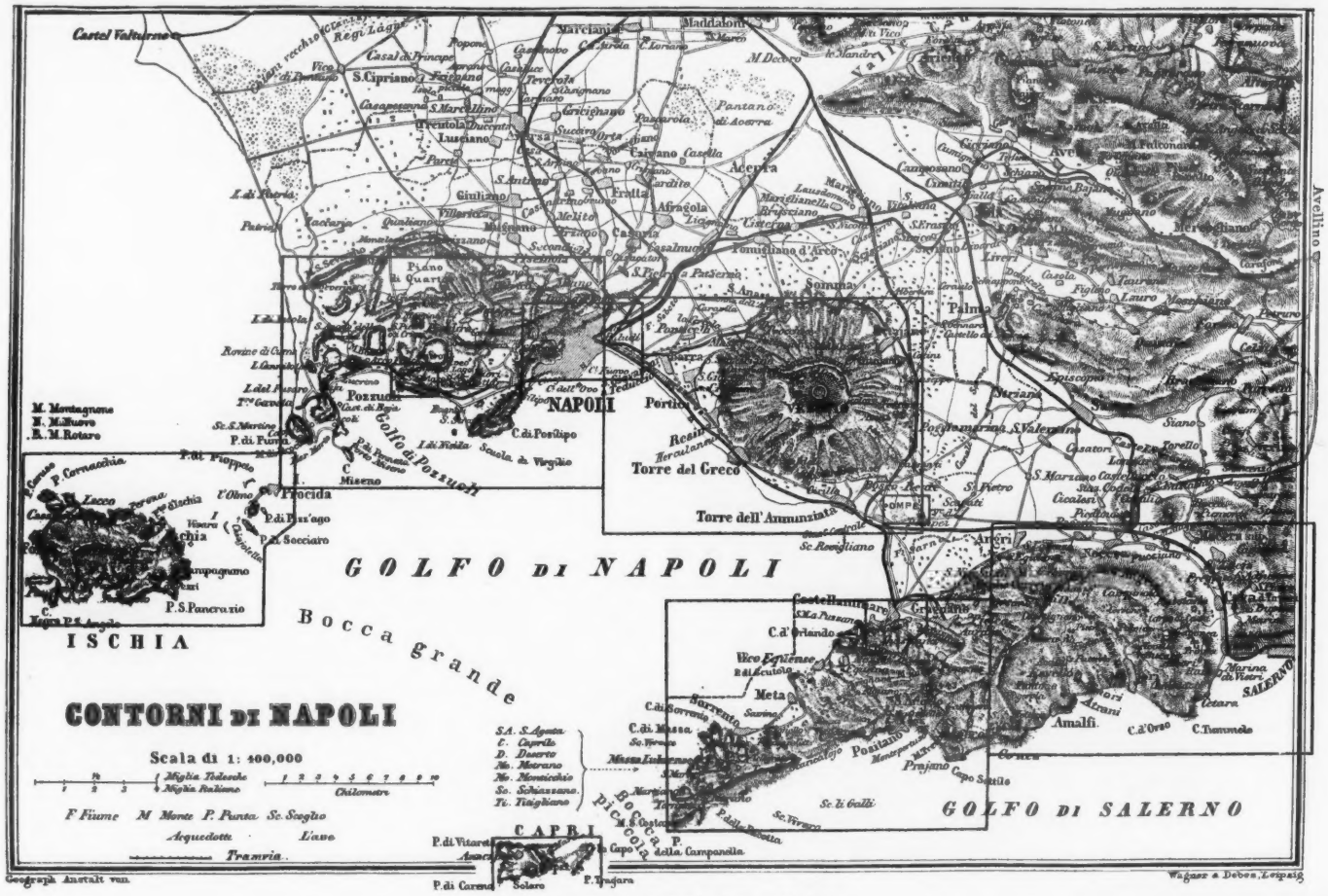
An instance of the effect of inspection and testing is here given:

When an army officer, inspecting the pistols of a large manufacturing concern in the United States during the war of 1862, rejected a large order because of variations in calibre and other slight deviations, he appeared to be doing a harsh act and one hard for the manufacturers to forgive. He really made the fortune of the manufacturers, because they at once doubled up on the care expended in the construction of the pistols, produced a first-class article for sale, and greatly increased their business. This is also a good instance of the benefit of government testing works to a country.

In conclusion, how shall the advantages of participation in the general industrial prosperity be gained?

The reply seems to come on all sides — establish research laboratories, testing laboratories, and technological schools or engineering departments in universities.

If a country somewhat behind in the race seeks to catch up and finds gifts from private fortunes are not available, it is surely good politics, as well as good patriotism, to use some of the taxpayer's money to start and carry on these good works on a liberal basis.



MAP OF MOUNT VESUVIUS AND VICINITY

THE VOLCANO VESUVIUS IN 1906

By T. A. JAGGAR, Jr.

In the spring of 1905 the summit of Vesuvius was unusually sharp-pointed, the crater was small, and a considerable growth in the height of the conelet on the summit took place during the year. In March of 1906 the height of the volcano above sea level was at least 4,350 feet. The active cone rises from a platform some 1,800 feet high, which is in reality the rim of an ancient stage of the cone when perhaps the volcano was much larger. This rim appears as a bench on the south and west and rises into a rugged encircling mountain scarp on the north and east, known as Monte Somma. Between Monte Somma and Vesuvius is the Atrio del Cavallo, a desolate valley 1,500 feet deep, with rugged cliffs on the side of Somma and long cone slopes on the side of the active volcano (see map). From the crater to Monte Somma the distance is a mile as the crow flies; from the crater to the Bay of Naples five miles in a southeast direction. Here the coast trends northwest. The places affected by the recent eruption and their distances from the crater are as follows: Boscotrecase, due south three miles; Torre Annunziata, south four miles; Ottajano, northeast, back of the ridge of Monte Somma, three and one-fourth miles; San Giuseppe, east-northeast, four and one-half miles, also shielded by the Somma ridge; Royal Observatory, one and two-thirds miles west-northwest; Naples, eight miles west-northwest. The Observatory is on a pronounced eminence of old lava, and both north and south of it are *coulées* of lava of recent origin. Past the door of the Observatory, much to the disadvantage of its magnetic instruments, run the cogwheel electric trams of the Cook Vesuvian railway. These made connection, prior to the eruption, with a very steep inclined plane funicular railway at the foot of the cone above the Observatory. There was a small station at the top and bottom of this last lifting device, which was designed to transport tourists to the immediate proximity of the high crater.

From the Italian point of view an eruption of Vesuvius means great outflows of lava — molten liquid rock. This outflow may be more or less accompanied by the *pino*, or pine-tree steam column laden with dust. The name is derived from a supposed resemblance in the form of the cloud to the Italian pine, with its straight stem below and spreading oval or funnel-shaped mass of foliage above. The present eruption was by no means unheralded. In 1904 there was flowing lava in the Atrio, checked coincidently with an explosion in the crater in September of that year. A year ago, in May, 1905, the cone split near the summit on the northwest side and very fluid lava flowed out. This flow, plainly visible from Naples, continued with varying activity until April 4, 1906, the time of the beginning of the present eruption. This eleven months of lava, lasting over a dry season (June, July, and August) and through another season of rain, might well give the scientific observers cause for apprehension. The contact of large masses of underground water with such incandescent slags could hardly fail to produce an explosion eventually. In the afternoon of April 4, 1906, a magnificent dense black "pine tree" was seen from Naples against a clear blue sky. The column rose obliquely 3,300 feet and then bent to the southeast. The small conelet caved in. The lava flows on the northwest had ceased to move, but a new mouth opened about 500 feet below the summit on the southeast side of the cone and gave vent to a flow which trickled southward. Heavy black sand fell at Naples.

On April 5 another lava mouth burst open 1,300 feet lower, and the next day a third 600 feet lower still and in the same radial line from the summit with the first two. Apparently the three mouths, in such a case, mark the extension of a rift or split from the crater outward and downward, like the crack from the top downward of an opening chestnut burr. The pressure of the rising lava finds it easier to rift the cone and so escape than to well up to the crater's edge. The common notion that the lava overflows the crater and rushes down in floods is erroneous. The lowest mouth was more than halfway down the mountain, and from this orifice nearly all the damage by lava was done. The stream divided in two, and part ran east and part south. The latter soon invaded cultivated land and destroyed some houses. The molten rock moved slowly but inexorably, like a mighty snake, seeking the lowest ground, following gullies when gullies could be found, but creeping onward always, crusting over the surface, cracking and making a tumble of porous bowlders at its front and on its

surface. Its most rapid movement was estimated at 16 feet per minute, excepting, perhaps, at the time of first outburst, when it was still quicker. On April 7 the lava was within a quarter mile of Boscotrecase, and it had flowed nearly two miles. Boscotrecase was a closely built masonry town, with a large church and numerous villas, and much of the town was on flat land at the confluence of two small valleys rather than on the intervening spur.

About eight P.M. of April 7 terrific explosions took place in the crater, and the "cauliflower" cloud rose three or four miles into the heavens. Large, red-hot blocks of rock were hurled out in a direction inclined upward to the northeast, towards Ottajano. These bounded down the flanks of the cone. Detonations increasing in violence and frequency were heard at Naples. The cloud was shot through with splendid electrical discharges from node to node of the dry, dust-charged steam whirls. The lightning was described by an observer at the Observatory as being nearly incessant and snapping, with a "rik-a-tak," spark-like quality, though frequently it was forked as in a thunder storm. At ten o'clock a fourth lava mouth opened, and new activity was given to the other flows, overwhelming Boscotrecase in two lurid streams and only stopping at the outskirts of Torre Annunziata. At eleven P.M. sand and *lapilli* fell in showers in Naples and in torrents on Monte Somma, Ottajano, and San Giuseppe. The overpowering weight of this snowstorm of gravel was too much for the flat and tiled roofs of the Italian stucco houses, and Ottajano simply *fell in*, the crumbling walls adding to the volcanic *débris*. There were no strong quakes, gases, thunderbolts, or heated blasts and no fires due to volcanic cinders. The material which fell at Ottajano retained no considerable heat. At Boscotrecase, however, crushed by creeping lava, fire necessarily aided in the work of destruction. At Ottajano many persons were buried in the fallen houses and still more in the church at San Giuseppe, where over two hundred were united in prayer at the fateful moment when the roof collapsed. There were almost no lives lost at Boscotrecase. The experience of Dr. Matteucci, Mr. Perret, and the carbineers at the Observatory was remarkable. Throughout the evening of April 7 the activity of the cone was recorded at the Observatory by incessant rocking, increasing showers of stones, some of which finally reached five pounds in weight, and a noise like a thousand boilers letting off steam — a sound of rushing winds. The vibrations were continuous for twenty-four hours. The

party dared not remain indoors, and they finally made a camp in the open. The conditions that night finally became intolerable, and the brigadier in charge gave the order to move down the mountain. They retreated to a house halfway down, and returned to the Observatory next day. The buildings were found intact, but dust had sifted into everything, necessarily injuring the instruments. At Naples, on the night of April 7–8, some slight earthquake shocks were felt and heavy detonations were heard. Mr. Perret, in describing to the writer the events at the Observatory, mentioned no heavy detonations. In this respect the experience of these observers suggests what was invariably the case at Mt. Pelée and Soufrière — that the sounds heard at a distance were greater than on the volcano itself. This implies some phenomenon of sound-shadow not as yet understood.

On April 8 the volcano was still pumping into the air its colossal dust cloud, charged with lightnings. The ash became finer and reddish in color. Sometimes, when the dust fell simultaneously with raindrops, it became agglutinated into tiny balls of the size of fine shot, which made distinct layers of such globules. On April 9 the crest of the cone was seen to be truncated and much lower than before the eruption. After this date the eruption steadily diminished in violence, until by the 23d, when the writer first saw the mountain, only quiet billows of white steam were rolling off, usually masking the crown of the cone with a heavy cap of cloud. During this period, however, there was one interruption to the tranquillity of those who remained at the Observatory. On the 18th of April, from noon until midnight a strong wind blew from the east-southeast and forced the deadly gases of the crater down to the Observatory hill. The air became irrespirable, and several persons were nearly overcome. It was surmised from the symptoms that carbonic acid gas and sulphuretted hydrogen were the principal gases present. At midnight the wind changed and the air became pure again.

Vesuvius on the morning of April 25, covered with its mantle of whitish dust, appeared like the pictures of snow-clad Fusiyama. The dust gave a weird, ghostly appearance to the landscape, mantling over and obscuring the contorted folds of ancient lava. The powdery appearance was confined to the volcano and its flanks and diminished with increasing distance from the crater. At about eight A.M. the writer, with three companions and a guide, started from the Observatory to make the ascent. The wind was blowing from the west. Great steam billows boiled up silently from the crater, and at intervals of a minute

or two either broke away in a cumulus cloud or settled down on the mountain, temporarily obscuring the crest. Throughout the day the wind increased, and as there had been little rain the sand and dust were borne in whirls over the mountainside, frequently obscuring everything, making breathing difficult, and penetrating eyes, ears, clothing, cameras, and field glasses most unpleasantly. The route followed first the lower railroad bed, and then the western profile of the cone straight up, along about the course of the demolished funicular. The railroad below the foot of the cone is occasionally recognizable; above it is almost obliterated. The stations are absolutely gone. Here there is a bent rail sticking straight up into the air; there is a stretch of track still tied together by the sleepers, but bent down the mountain at a right angle, as though the whole roadbed for a short distance had been swept downward by an avalanche. Everywhere a pall of sand and gravel from 1 to 6 feet deep, scoured and etched by the wind to show cross bedding, ripple-drift patterns, and arrow-shaped accumulations in the lee of pebbles or other stationary objects. Here and there on the higher slopes there are large, angular, new-fallen rock fragments up to five feet in diameter. Much of the upper cone slope is practically hard rock, the descent being so steep that the new material slid down and accumulated in drifts at the bottom. The slope of the cone makes an angle of about 30° with the horizontal.

Climbing the higher slope was not especially difficult, as the footing on the spurs was hard, though the gullies were filled with deep, soft sand. By following a zigzag route the steepest places were avoided. The hard spurs are either actual bed rock of old lava or closely plastered and cemented rock fragments so packed that they could slip no farther. The slope is so steep, especially in its middle portions, that great care is necessary to prevent starting bowlders down on climbers below. The steepness increases to a point near the crater's edge, when the slope becomes a little flatter. A volcanic cinder cone is peculiar in that the inflections of its profile are such that the actual edge of the crater is in view at all times; what appears to be the summit *is* the summit, as may be seen by the steam billows just beyond, and when the edge is reached the abrupt precipitous fall-off is very sudden. Near the border of the crater the gentler slope permitted accumulation of deep gravel beds, making the last steps of the ascent very arduous. This was enhanced by increased violence of the wind, and the bombardment of tingling sand grains and dust whirls made it impossible to see or

breathe unless one turned one's back to the gale. Even then it was frequently necessary to stand still and shut the eyes and wait for a calmer spell, so intolerable was the eddying sand which obscured everything and so distracted the staggering climber as to make it impossible to go on. The ground was quite hot at the crater's edge, and the sulphurous odor of the vent became perceptible. At no time, however, was this at all disagreeable, as the climbing party was on the windward edge. The suddenness of the appearance of the edge was startling, and it was necessary to be cautious in approaching it as it overhung in places and might easily cave in. The outer slope changed its appearance in no respect. It was simply terminated by a precipice in the opposite direction; and while a howling gale amid opening and shutting clouds blew from the rear, in front was a steaming abyss with rapid-rising billows seen above and a yawning chasm below, showing dimly some smoking crags and clinging bowlders in the foreground. The slope extended down into steam and heat, and right and left the angular edge curved away into the sand mist. There was no lava visible, though one member of the expedition thought he caught a glimpse of something glowing through the steam. The inner cliff sloped down at an angle of from 35° to 40°, and the slope consisted of sand and broken rock fragments. Stones gathered by reaching over the edge were quite hot. About 120 feet down the inner slope appeared a number of jutting ledges at a common level, marking a bench of hard lava which had been more resistant to the caving in of the new crater. The inner face of these ledges appeared to be nearly vertical. Beyond was a steamy blank. Brownish or bluish fumes rose from cracks in the ledges. No noise could be heard above the roar of the windstorm. A little sunlight sifted through the sand clouds now and then, and during partial lulls in the wind photographs were taken, some of which produced satisfactory negatives. The curvature of the edge of the crater is quite irregular, with embayments here and there and variations in height at different places. Small cavings in and the whirl of the eddy within the rim made every now and then a purling brown vertical dust column, which moved along the edge a short distance after the fashion of the snow whirls seen on a Swiss *arête*. Indeed, the cleanly moulded sandy edge of the crater in many places resembled the overhanging scarp of the high, wind-scoured snows of the Alps.

Aneroid measurements made the summit 2,000 feet above the

Observatory and between 350 and 400 feet lower than before the eruption. It was estimated from what could be seen of the curvature of the crater that the new bowl is between one-fourth and one-half mile in diameter. The east-west diameter is much greater than the north-south, as may be plainly seen from different points of view at a distance. Therefore the new crater is somewhat elliptical. It is notched outward and downward on the northeast side, and it was the material there fallen in and abraded away which was hurled out on Ottajano. The depth of the crater is more than 150 feet — how much more could not be told.

The party remained long enough on the crest to secure specimens, photographs, and notes, and then returned down the soft sand of a depression on the northwest side of the cone. The only trace of the upper funicular railroad seen was a short stretch of half-buried track about halfway up. The appearance of the faces of the explorers when they reached the Observatory was ludicrous in the extreme. Eyes, noses, ears, and hair were plastered with gray dust, and the original color of their clothing was unrecognizable. The writer's camera, a new kodak, was no longer new.

The materials of the sand and dust are mostly ancient lavas from the walls of the vent and from the demolished cone. Professor Bassani,[1] of Naples, suggests that the peculiar sequence of fallen material — first black sand, then glassy *lapilli*, and lastly red dust — has the following significance: the black sand is probably composed of powdered black recent lava of the high conelet of 1905; the glassy *lapilli* are the sherds and droplets of the lava of the present eruption, partly involved in the explosions from the crater during the period of the greatest flow at Boscotrecase; the red dust is made of the older rusty rocks of the deeper parts of the volcano, attacked during only the last part of the eruption. This theory has not as yet been tested by microscopic investigation.

The most striking and unexpected features of the ruin wrought by lava at Boscotrecase are the absence of damage by fire in those parts of the town not invaded but adjacent to the lava, and the bowldery surface of the lava itself. It is a great field of tumbled, scoriaceous, basaltic blocks of all sizes, not a snaky tangle of congealed slag such as appears in many of the older flows. Apparently the gases emitted made the upper part of the flow very porous, and then this portion

[1] Rendiconti della R. Accademia delle Scienze F. e M. di Napoli. Fasc. 4. April, 1906.

solidified and cracked up into large blocks, while the lower part remained fluid and moved forward. This tumble of blocks seems to have acted like the moraine at the front of a glacier, and in the same manner it was shoved forward. Probably its presence at the border of the incandescent mass partly protected the adjacent buildings from fire. Another cause of immunity from fire was the masonry construction with comparatively little timber — in marked contrast with the flimsy redwood architecture which was so largely responsible for the conflagration at San Francisco. The scene at Boscotrecase is none the less desolate: villas cut in two, with one-half among the lava lumps, the other standing; the border of the lava field more than 16 feet high in places, filling railway cuts, streets, sliding into cellars, and banked against the stately ruin of the church. The stream had forked about a spur, where vineyards are, and left them untouched; it had followed lower land, where the town was, and had crushed, swallowed up, overrolled, burned, and digested everything in its immediate path, leaving a high black sweep of clinkers and broken masonry.

Seen from the mountain above, the ruins of Ottajano present a still more desolate spectacle. They appear not unlike St. Pierre in Martinique as seen from the sea. The cause of the Ottajano disaster was totally different from that at Boscotrecase. Ottajano could not possibly be reached by a lava flow from the present cone, for the high ridge of Monte Somma directly intervenes. But the distance of Ottajano from the centre of disturbance is only a quarter of a mile more than that of Boscotrecase, and what could not be reached with lava was attacked by bombardment. The volcano, probably partly dammed within by welling lavas on the Bosco side, vomited its earthy jets obliquely outward on the opposite Ottajano side. It there tore away the walls of the crater and hurled many tons of gravel and rocks on Monte Somma and beyond it. On the edge of the Monte Somma cliffs there is a huge new block of rock five feet in diameter, which was thrown a mile and landed where it now lies embedded. The ruin at Ottajano and beyond it at San Giuseppe was due to a simple, single cause — falling sand and gravel. There was no serious earthquake, fire, lightning, or wind. The sand and *lapilli* at Ottajano reach a depth of from 3 to 3½ feet on the level. The stones averaged one-third inch in diameter, but there were many as large as an apple. The roofs have caved in, carrying with them the *débris* of the walls, frequently shifting sidewise and producing puncture, rupture, or total crumbling of the loose

masonry. Vaults of sufficient thickness, arches, and dome-shaped huts were the only structures which resisted the attack. The narrow streets are piled high with the sand and fallen rubble, the footpaths through them now following a course far above the pavement. The survivors report bad air, but no asphyxiating gases. The corpses were not found in the streets, but in the houses, where death was occasioned by entombment in the ruin. The window panes were broken, especially on the side away from the volcano, indicating that there was an indraught of wind towards the mountain at the height of the eruption. Some of the flying pebbles were endowed with such high velocity from their long flight miles up, out, down, and in, that they cut clean holes through the glass.

The distinctive feature of this eruption of Vesuvius was the large amount of ash thrown out and the relatively small lava flows. The ash is believed to be mostly broken rock matter of older eruptions. Steam was the motive power, pulverizing and hurling skyward the materials of the disrupted cone. The crater suffered much in this process, its rim losing several hundred feet of height and its diameter increasing to many times its former size. With respect to these things, the present eruption of Vesuvius more resembles the Pompeian eruption than the later outbreaks characterized by lava. In magnitude the eruption of 1906 is comparable to the greater eruptions since 1631, but there is no reason to believe it of extraordinary intensity. It was unfortunate in its results, as human habitations were in the track of its discharges. Ottajano and Boscotrecase have both suffered in previous eruptions; their distance is within the danger limit. The destruction of the market in Naples by a collapsing roof was such as proper precautions might have avoided. It in no way indicated unusual violence at long range. The down-rushing cloud of steam and sand which was so conspicuous a feature in the Caribbee Islands in 1902 was not in evidence at Vesuvius, and has never been observed there since the year 79; it was possibly a feature of the great eruption of that year, when Pompeii and Herculaneum suffered.

As a disaster to human life and works, two principal agents were operative: falling gravel and flowing lava. The down-blown gases at the Observatory on the 18th of April were a third source of danger, but not at the distance of ordinary habitations. Beyond five miles no great amount of damage was done. If we add to this enumeration the blast which destroyed St. Pierre — a totally different phenomenon —

we shall have a summary of all the principal known causes of volcanic destruction — falling roofs, lava, and steam tornado. In all three cases construction is possible which will greatly protect human life. If such construction were required by law within the danger zone, volcano insurance, both of life and property, might become a less extraordinary risk. Dome and arch construction of roofs would have saved Ottajano; large cellars with iron doors were demonstrated in the West Indian eruptions as proof against the black tornado and capable of saving life; at Boscotrecase, had the town been built on the higher ground and protected by a suitable earthwork on the volcano side, there might have been no damage except to the farm lands in the valleys. Instead, the town was in the bottom land at the confluence of gulches, which guided the lava towards it.

The coincidence of the San Francisco earthquake with the Vesuvian disaster in no way indicates any terrestrial connection. Both occurred in the spring of the year. Possibly some influence of the recent rainy season in both places may have been operative. The destruction of property in both cases was occasioned by the failure of human foresight and the neglect of those concerned to study *practically* the question of forewarning. As geology is now progressing, the practical side of disaster from earth forces will never be studied as a distinct branch of science unless it is endowed as such. There is some work of this sort done in Japan, because earthquakes are there a constant menace, and in Europe seismographs are maintained at a few stations, largely by private individuals. In the United States very little has been done, although the whole Pacific coast is an earthquake and volcanic belt. It is not merely to guard against earthquakes and volcanoes that research is needed. Landslips, floods, "tidal" waves, and various marine phenomena are manifestations of earth physics affecting man which demand practical study with a view to forewarning and protection. That such means of preserving human beings and their works are worthy of study may be seen by comparison with some existing institutions. The armaments of the world are a source of protection to nations, maintained among the largest items of the public budget. Japan has lost more lives by earthquakes and their consequent tidal waves than in the whole Russian War. The United States Weather Service is maintained to study the movements of the atmosphere and thereby aid commerce, navigation, and the public safety. This service publishes a monthly bulletin and many maps. There is no like estab-

lishment anywhere in the world to study the movements of the earth and the interaction of the earth with its watery and atmospheric envelopes. Astronomical observatories are at work everywhere. Occasionally they make a practical contribution to navigation or geodesy, but almost all of their modern work is theoretical. None the less it is justly recognized as of the highest value to the progress of mankind. And yet for the devising of suitable apparatus to study our own earth, and for the maintenance of such study, there is no institution in existence. The nearest approach to such an establishment was the appropriation of money by the Carnegie Institution for a geophysical laboratory. This laboratory is doing theoretical work in pure science. But such work, following the methods of the physical and chemical laboratory, does not concern itself directly with *the earth as a laboratory*. There is needed an institution which shall be devoted to the observation and measurement of earth movements, and primarily with a view to the practical application of such studies. The practical application of first importance is the preserving of human life and property. Secondly and eventually, the accumulation of data by long observation and exploration will inevitably lead to discovery of new uses for earth energy, whereby the sources of terror and destruction now so fatal will be turned to man's account.

It is worthy of remark that the United States has now more reason than formerly to give attention to seismo-volcanic study. Porto Rico and the Panama Canal are in regions of earthquakes and earthquake waves; the whole Pacific coast from Lower California to the Alaskan Range is a field of intense seismical activity and much recent volcanism. The Aleutian chain of islands consists of active volcanoes. The Hawaiian Islands contain the most remarkable lava outpourings in the world. The Ladrones are volcanic. The Philippines, like Japan,[1] contain many active volcanoes and have frequent earthquakes. The Jesuit fathers in the Philippines have for many years maintained seismographic observatories, and the Japanese physicists and engineers lead the world in precise investigation of earth movements and earthquake construction.

[1] See Publications of the Earthquake Investigation Committee in Foreign Languages, No. 19, Tokyo, 1904. "Recent Seismological Investigations in Japan," by Baron D. Kikuchi.

WATER-TUBE BOILERS FOR MARINE SERVICE[1]

By WILLIAM LEDYARD CATHCART

The water-tube boiler has replaced the fire-tube type in all modern war vessels, from torpedo craft to battleships. While in a few constructions of comparatively recent years the fire-tube boiler is still found as part of a composite plant of both types, it is not probable that such combinations will again be installed, since the opportunities thus given for tests of both boilers, under precisely similar conditions, have confirmed the results of many previous trials of complete plants of both types and have shown the unquestionable superiority of the water-tube class for all naval uses. It seems safe to predict that eventually this history will be repeated in the merchant marine, since most of the reasons for the displacement of the fire-tube boiler from warships apply also, in greater or less degree, to all seagoing steamers.

There are two stages in the generation of steam: combustion in the furnace and transmission of heat in the boiler proper. The first of these actions is similar in all boilers; in the second there is a marked difference between the fire and water-tube types in this, that in the former the gas currents, after leaving the furnace, are subdivided within tubes which the water surrounds, while in the latter the reverse is the case, the water and steam passing through the tubes. Let us consider the effect of this difference upon

Heat Transmission through Heating Surface

The laws governing such transmission in a boiler of any class are, as a whole, but little known. The final result is the effect of several actions: convection currents and slow internal conduction in the gases, transmission by convection and exterior conduction from gases to metal, internal conduction within the latter, and external conduction

[1] A lecture delivered before the Naval Architectural Society of the Massachusetts Institute of Technology.

from it to the water, and, finally, convection currents and feeble internal conduction within the mass of the water or mingled water and steam.

As to this complex series of operations, there are known only the law of heat transmission through the metal, the conductivity of water and, approximately, that of the gases. The former conductivity is, according to Lord Rayleigh, 115 times less than that of iron, while according to other investigators it is about thirty-five times greater than that of the combustion gases. While this evidence is indirect, it seems clear that heat passes with much greater difficulty from the gases to the metal than from the latter to the water — a deduction which test observations support, since they show always a much greater difference of temperature at the fire side than at the water side of the metal.

Heat Transmission in Cylindrical Boilers. — These temperature differences are vital factors in such heat transmission. Rankine[1] gives as "a rough approximation" for heat transmission through boiler heating surface a formula in which the rate of conduction varies directly as the square of the difference of temperature between the gases and the water. Later Blechynden[2] showed, from the results of his experiments, that the heat transmitted, "per degree difference between the fire and the water, is proportional to the square of the difference between the temperatures at the two sides of the plate." Rankine's formula, however, was based on the evaporation of cylindrical boilers, in which water circulation is admittedly defective, and Blechynden's experiments were conducted on a boiler which was simply a vertical, cylindrical shell. The conclusions of both have, hence, the same objections with regard to their strict application to a water-tube heating surface.

The Effect of Motion on Heat Transmission. — The state of motion of the water and gases is a further and most important factor in heat transmission. Péclet long since showed that a rapid renewal of the layers of liquid and gas, in contact with a metallic plate, was essential for efficiency in heat transmission from one medium to the other and through the plate. Later Professor Ser[3] found quantitatively the

[1] Manual of the Steam Engine, London, 1874, p. 260.

[2] Transactions Institute Naval Architects, 1894.

[3] Traité de Physique Industrielle, Paris, 1887, 1891, I, II.

effect of motion, at a uniform temperature difference, with regard to water when passed through a horizontal copper tube surrounded by a casing, the space between tube and casing being filled with steam kept at a constant temperature. Beginning with a water velocity of 0.1 metre per second, the speed was increased gradually until it became 1.1 metres. The heat transmission, rising with the speed, was 2.7 times greater, per unit of surface and of time, at the end than at the beginning.

In comparatively recent tests by Austin[1] heat from boiling oil was transmitted through the shell of a cylindrical, wrought iron boiler, open at the top and filled with water, the latter being thus boiled, both at rest and when violently stirred by a propeller. It was found that with unstirred boiling water the resistance to heat transmission at the interface between the iron and the water was equal to that of iron 1.2 to 2 cm. thick, the range being due to the state of ebullition of the water; and also that rapid stirring reduced the resistance to that of about 0.75 cm. of iron.

As to the motion of the combustion gases, Péclet,[2] in discussing the transmission of heat from one gas to another and through a metal plate, says:

"The quantity of heat which traverses the plate is determined solely by the difference of temperature of the two gases, the absorbing and emitting capacities of the two surfaces of the plate, and, above all, by the movements of the layers of gas in contact with these surfaces. We see thus that in all cases the rapid renewal of the layers of gas or liquid which touch the surfaces of the metallic plate has a very great influence on the transmission of heat, but that this condition is of much greater importance with gases than with liquids."

Again, Professor Ser — who extended the experiments previously noted to the investigation of the effect of motion on the transmission of heat to air or gases — found a marked gain in such transmission from an increase in the speed of the gas.

With regard to the relative directions of the heating and heated currents, Rankine[3] says:

"When heat is to be transferred by convection from one fluid to

[1] Mitteilungen über Forschungsarbeiten, Verein deutscher Ingenieure, No. 7.

[2] Traité de la Chaleur, Paris, 1860, I, p. 393.

[3] Manual of the Steam Engine, London, 1874, p. 261.

another through an intervening layer of metal, the motion of the two fluid masses should, if possible, be in *opposite directions*, in order that the hottest particles of each fluid may be in communication with the hottest particles of the other and that the *minimum* difference of temperature between the adjacent particles of the two fluids may be the greatest possible."

Circulation in Water-Tube Boilers. — In all boilers the gases are in rapid motion. As to the water, however, an important difference between the fire and water-tube types is that in the former the water currents lack direction and the circulation is not only irregular with regard to the entire extent of the heating surface, but is, as a whole, relatively sluggish. In water-tube boilers, on the contrary, the circulation is controllable and depends on the tube arrangement.

Bertin[1] divides water-tube boilers, with regard to circulation, into three classes:

1. *Limited Circulation.* — These are serpentine or coil boilers, in which there is no circulation except that necessary to replace the water evaporated. The generating coils receive the feed water at one end and discharge the steam at the other.

2. *Free Circulation.* — The chief characteristic of this class is the presence of a vertical, flat water space at the front and another at the back of the boiler, the two connected by horizontal or slightly inclined tubes, and each joined at the top to a steam and water drum. The water passes from the drum through one space and the tubes and then returns, partly as steam, through the other water space to the drum. The circulation is much more rapid than in the previous case, and the steam escapes from the heating surface much more freely.

3. *Accelerated Circulation.* — In this class the main feature is the direction of the generating tubes, which connect an upper steam drum and a lower water drum, and are set as nearly vertical as possible. Large downtake tubes return the water from the former drum to the latter. Maximum rapidity of circulation is attainable in this form.

Of boilers designed for general marine service, the Belleville, the D'Allest, and the Yarrow may be cited as examples of the first, second, and third classes, respectively. In general, the circulation should be sufficiently rapid to secure full efficiency in heat trans-

[1] Marine Boilers, London, 1905, p. 34.

mission and to sweep away the steam from the heating surface. For use at sea the boiler should have a circulation which is assured and positive in direction under all conditions of pitching and rolling. A circulation which is sluggish, spasmodic, or capable of temporary reversal in a seaway is liable to cause burned tubes.

Factors of Circulation. — The forces acting to produce water circulation are essentially the same in all water-tube boilers of "free" circulation having inclined tubes, and also in those of "accelerated" circulation. The Babcock and Wilcox marine boiler has some of the characteristics of both of these classes, as defined by Bertin, although its tube inclination is somewhat greater than that laid down for "free" circulation; it has no general "water spaces," but independent headers for each element, and the centre of its circulating tubes is at the water level in the drum.

As shown in Figure 1, the feed water enters the steam and water drum at the top and front of the boiler. It then passes downward through the front "header," which is essentially a corrugated box of rectangular section. From this header it ascends through the generating tubes, which are inclined usually at an angle of about 15° with the horizontal. In its passage through these tubes it receives the greater portion of its heat, so that, partly as steam, it traverses the rear header — which is similar to that at the front — and the horizontal circulating tubes in its return to the drum. The normal water level is the plane of the centres of the circulating tubes and drum. The steam leaves the latter through a dry pipe at the top.

The factors[1] which combine to produce circulation in such a circuit — which includes two approximately vertical sections, one (from the water level in the drum downward) of solid water, the other, during rapid generation, composed of water and steam — are:

1. The reduction in density of the water in the ascending column from the rise in temperature due to its passage through the generating tubes. This effect, small in any event, is still further reduced by rapid circulation, which acts to keep all water in the boiler at or near the temperature of the steam. Hence the effective action of this reduced density is practically limited to the interval between the lighting of the fires and the formation of steam.

2. The difference between the densities of the descending and

[1] For discussion see Marine Boilers, Bertin, London, 1905, p. 400.

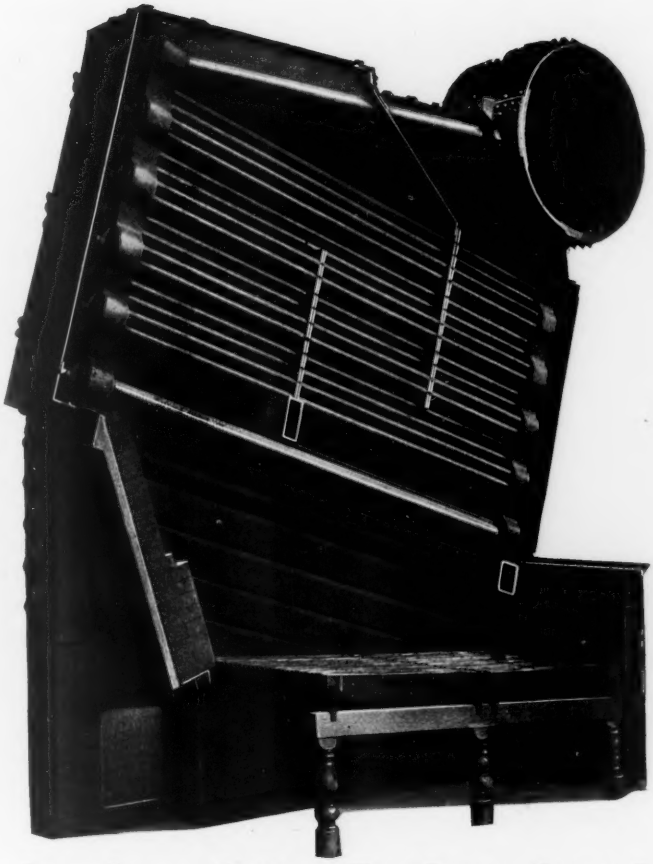


FIG. 1.— SECTION OF BABCOCK AND WILCOX BOILER OF "LOUISIANA"

ascending columns, due to the former being composed of solid water, the latter of a mixture of water and steam. For example, if the discharge from the circulating tubes is three parts of steam and two of water, the circulating force at the top of the descending column would amount to three-fifths of the specific gravity of an equal column of solid water, less, of course, the loss of head due to friction, bends, etc.

Speed of Circulation. — General indications as to the variations in the speed of circulation in the successive tube rows of boilers of "free circulation," as defined by Bertin, are given in the report of a trial by Fuchs[1] of such a boiler having eight rows of tubes, with a superheater fitted above the middle of the top row. The steam pressure was 11.9 kilograms per square centimetre, absolute, and the evaporation 24.85 kilograms per hour per square metre of heating surface. The velocity of the water was measured by the speed of small propellers inserted in the tubes. The water velocities, in metres per second, were: in the first (lowest) row, 0.98; in the fourth row, 0.328; in the eighth (top) row, 0.033.

Tube Inclination and Evaporation. — Watt[2] experimented upon a small model boiler so constructed that the tube inclination could be changed gradually from the horizontal to the vertical. The evaporation per unit of surface was found to be highest at a tube inclination of 10° with the horizontal; at 15° it was 97 per cent. of this maximum; at 90°, 59 per cent.; and when horizontal, 88 per cent. Other things equal, evaporation depends less upon water circulation, providing the latter is fair, than upon the manner in which the gas currents impinge upon the tubes and circulate among them. Watt's results, therefore, apply specifically only to the conditions of his tests.

Relative Efficiency of Heating Surface. — Watt also concluded from further tests "that practically 60 per cent. of all the steam generated in any water-tube boiler, with tubes at any angle, is generated in the first or nearest row of tubes to the fire" — a result due mainly to radiant heat and the fact that the gases have their highest temperature and velocity when they meet this tube row.

Practical Limits of Water Circulation. — In the progress of the water-tube boiler primary importance was at one time given generally

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[1] Generator-Kraftgas- und Dampfkessel-Betrieb, Berlin, 1905, p. 70.

[2] Transactions of the Institute of Naval Architects, 1896.

to very high speeds of circulation. This view is still held by some of the foremost authorities. For example, M. Bertin [1] says:

"Everything possible should be done to assist the circulation by encouraging all that tends to produce steam, removing, as far as possible, any causes tending to reduce the circulation, as the efficiency of a boiler increases with the speed of the circulation."

The opposing view is indicated by the following:

"It is claimed by some manufacturers that the rapid circulation of water in their boilers tends to make them more economical than others. We have as yet, however, to find any proof that increased circulation of water, beyond that usually found in any boiler, will give increased economy. We know that increased rate of flow of air over radiating surfaces increases the amount of heat transmitted through the surface, but this is because by the increased circulation cold air is continually brought in contact with the surface, making an increased difference in temperature on the two sides, which causes increased transmission. But by increasing the rapidity of circulation in a steam boiler we cannot vary the difference of temperature to any appreciable extent, for the water and the steam in the boiler are at about the same temperature throughout." [2]

As to this, it may be noted that the experiments of Professor Ser, previously quoted, which showed a marked increase in heat transmission with the rise in the velocity of the water, were conducted at a practically constant temperature difference between the heating and heated media. Further, the tests of Austin, also cited, indicate that — also at a practically constant temperature difference — motion of the water reduces the resistance to heat transmission at the interface of the metal and water.

Increase in temperature difference gives, *per se*, a rise in heat transmission; but if the results of these two series of experiments be accepted it is clear that at a constant temperature difference a greater velocity of the water augments the rate of heat transmission.

Boiler economy is, however, dependent, not only upon the efficiency of heat transmission to the water, but also upon that of heat transmission from the gases. Granting that a greater velocity of the water makes possible a higher rate of heat transmission to it, there must be

[1] Marine Boilers, London, 1905, p. 417.

[2] Steam Boiler Economy, Kent, New York, 1904, p. 299.

secured, also, a proportionate rise in heat transmission from the gases in order to obtain an increase in boiler efficiency corresponding with that in water speed.

In discussing these conditions Professor John Perry, F.R.S., said[1]:

"One small tube conveying hot gases, dragged through at an enormous velocity, and a concentric tube conveying water in the opposite direction at great velocity — they had in that combination a method of giving up heat which was fifty times as great as what occurred in an equal amount of heating surface in the best existing boilers."

This combination would be, theoretically, most advantageous, especially in its control of the direction and in its minute subdivision of the gas currents, which subdivision would act to offset the low conductivity of the gases. It represents, in effect, the views of Péclet and Rankine carried to what would be a logical but, at present, impracticable extreme.

The difficulty of effective abstraction of heat from the gases is the limitation which prevents the increase in efficiency otherwise possible by extreme speeds in water circulation. Practically, therefore, all that is necessary is a circulation which is sufficient to sweep away bubbles of steam from the heating surface, thus preventing overheating, which is active enough to keep all water in the boiler at about the same temperature, and which is absolutely "free," so that when required the boiler may be forced to the limit fixed by its heating surface, combustion space, and baffling.

In boilers for land service a circulation beyond the limit otherwise necessary is sometimes of value in using feed water containing a considerable amount of substances tending to form scale or other incrustation. The greater scouring action of the water with more rapid circulation acts to prevent the deposition of such substances, especially when the boiler is below its normal load.

Heat Transmission from the Gases. — In a marine water-tube boiler whose circulation is either "accelerated" or sufficiently "free," the heat transmission at the water side of the heating surface may be considered as sufficiently rapid to transfer at once all heat received by the metal. Hence, other things equal — as to the rate of combustion per square foot of heating surface, the condition and relative value of the latter, the completeness of combustion, and the losses from radiation

[1] Transactions of the Institution of Engineers and Shipbuilders in Scotland, XLII.

and air leaks in the casing — it is evident that in practice the relative efficiency of such boilers depends upon that of heat transmission from the gases, since this determines the temperature of the latter at exit to the chimney.

The principal conditions affecting the amount of heat transmitted from the gases to the heating surface are:

1. The low conductivity of the gases, which, as stated, is about thirty-five times less than that of water. The condition can be met most effectively only by splitting the gas current into thin sheets in its flow past the heating surfaces.

2. The duration of the contact of the gases and heating surface. This at best is very brief. In some cases the gases pass through the boiler in three-fourths of a second. This condition shows the advantage of baffling to form a circuitous route for the gases in order to increase the distance traveled by them in contact with heating surface.

Speed and Direction of the Gases. — The principles relating to these factors in heat transmission have been noted previously. Rankine's dictum as to the opposing directions of the currents of gas and water, while theoretically correct, would be of full value in practice only if applied to sheets of gas sufficiently thin to overcome appreciably, during the brief duration of contact, the low conductivity of the gases.

In the water-tube boiler these sheets in passing between the tubes are relatively thick, and the gases move at very high velocity in the path of least resistance. Hence to remedy feeble conductivity and to give convection as full action as possible the gas currents should be opposed and broken by impinging, preferably at right angles, upon staggered tubes.

Baffling. — In water-tube boilers the total space for the passage of the gases from furnace to uptake is, as a rule, relatively large as compared with the furnace volume. Hence, under forced draught especially, the gas currents, if not directed by baffling, will take the shortest way to the smoke pipe, thus meeting only a part of the heating surface and leaving the remainder ineffective. In many of the earlier water-tube boilers the gases were practically shunted up the smoke pipe, so that the latter, even with natural draught, was heated to a dull red at the base, thus increasing the draught and reducing efficiency by drawing in an excess of air.

In order to conduct the gases over the entire heating surface and to increase their travel and duration of contact, a system of baffling is

absolutely essential in every water-tube boiler. In some boilers having "accelerated" circulation, and hence approximately vertical tubes, the latter, in the row next the furnace and in that next the casing, are so set as to touch tangentially throughout the lengths of these two rows, thus forming "water walls" which enclose the gases in their passage horizontally between the remaining rows. In other boilers of similar circulation a perforated plate is set on the outer row of tubes, which plate by offering some resistance to the flow of the gases acts to give the latter a more equal distribution. In the Babcock and Wilcox boiler baffling is effected by sheet-metal partitions set perpendicularly to the tubes, which partitions divide the total space into three approximately equal and consecutive passages.

Some water-tube boilers cannot be baffled at all without destroying the special characteristics which are their chief reason for existence. As a result they are most wasteful under forced draught. Baffling should in any case be so designed as to offer the least possible resistance to the flow of the gases, since such resistance increases the power required, under forced draught, from the blowers.

Summary. — With regard to heat transmission, any water-tube boiler having a circulation sufficiently "free" or "accelerated" is superior to the marine cylindrical type in so far as the water side of the heating surface is concerned, owing to the subdivision of the water within tubes and the active and sustained circulation. As to the gases, however, the reverse is the case in general, since in the cylindrical boiler the total volume of the gases is not only subdivided in tubes, but retarders may be used, as in the Howden system, to combat low conductivity and increase convectional action. Whitham,[1] in trials of a horizontal fire-tube boiler, found that these appliances gave an economic advantage when the boiler was pressed, varying in his tests from 3 to 18 per cent.

Hence in water-tube boilers generally the heating surface is not, as a whole, as effective as that of the cylindrical type, although portions of it, where the gas circulation is most favorable, are unsurpassed in efficiency. A thorough system of baffling, however, in such boilers as are fitted for it overcomes largely the difficulties with regard to the gases.

These conclusions apply only to clean heating surface. Some

[1] Transactions of the American Society of Mechanical Engineers, XVII.

water-tube boilers with straight tubes are so constructed that the water side of the heating surface is fully accessible, while it is possible, also, to keep the outer side of the tubes almost wholly free from soot while running and to cleanse it thoroughly when the boiler is out of use. In such cases the efficiency of the heating surface as to cleanliness can be much more readily maintained than in the cylindrical type.

Requirements of Water-Tube Boilers for General Marine Service

"Express" Boilers. — Water-tube boilers for marine service may be divided generally into the "small-tube" and "large-tube" forms. The former class — the "express" type — is that used in torpedo craft and similar vessels where extreme speed for brief periods is the principal consideration, and hence where minimum weight and the ability to stand high forcing, without special regard to economy, are essential. These objects are attained by providing an excess amount of heating surface in thin tubes of small diameter, closely spaced and arranged for "accelerated" circulation; by carrying the least possible amount of contained water; and by making the casing and fittings relatively very light.

"Large-Tube" Boilers. — The "large-tube" boiler, on the other hand, is intended for general service in battleships, cruisers, and merchant steamers. Since such vessels must make long voyages in all weathers, and are at times far from a repair base, boilers for this service should have qualities of endurance in various respects which are not required from the "small-tube" type. Hence they have more contained water, are less sensitive in steaming, and are of stronger build and greater weight than "small-tube" boilers. "Large" tubes may be described generally as those of 2 inches in diameter and upward, although this dimension is not wholly accurate for differentiating these two classes.

Requirements. — The following requirements should be considered in comparing water-tube boilers designed for general service at sea:

1. *Efficiency.* — The boiler should have such combustion space, heating surface, water circulation, and baffling as will give it high efficiency at its usual rate of steaming, with, in war vessels, no serious reduction in that efficiency at the limit of reasonable forcing. This

limit, under service conditions in the United States Navy, appears to be a consumption of about 40 pounds of coal per square foot of grate surface.

2. *Sustained Efficiency.* — For sustained efficiency the tube system should be so arranged that both sides of the heating surface can be kept clean. Despite all precautions some scale is sure to be deposited, owing to leaky condensers, defective valves, or an occasional unauthorized dose of salt feed when low water is feared. It is also impossible to keep the tubes entirely free from oil, since, although there may be no lubrication of the main cylinders, it will enter through the exhaust from dynamos, pumps, and other auxiliaries. Sediment may form also from oil and rust or the use of muddy water.

For these reasons the interior of the tubes should be readily accessible, both for inspection and the use of scaling cutters, while ample means should be provided for blowing the soot from their exterior while under way and for thoroughly cleaning the boiler when out of use.

3. *Size of Units.* — The boiler should be capable of construction in the form of single units of large power. A large number of small boilers means much added complication in piping, valves, fittings, and pumps, with a corresponding increase in the cost of maintenance and the care required in operation.

4. *Sectional Construction.* — Sectional construction of the tube system, *i.e.*, the division of the heating surface into a number of similar elements, each (in action and fitting) independent of the others, is an advantage of much importance in obviating all strains due to unequal expansion and contraction and in making possible the erection of the boiler in sections on the vessel, thus avoiding all cutting of the decks in reboilering.

5. *Weight.* — Weight saving in both boiler and contained water is an inherent advantage of the water-tube system as compared with the cylindrical type. This advantage should not, however, be pressed to extremes in boilers designed for general service at sea. It is false economy in such cases to limit the area and thickness of the heating surface, to build a light casing which will warp and leak, giving rise to large heat losses, and to have so small a volume of contained water that incessant vigilance is required to maintain its level in the gauge glass and to prevent the burning of tubes. The added weight required to give full combustion space, ample heating surface, a reasonable

amount of contained water, and an adequate casing will in service be much more than offset by the reduction in the weight of coal required for long runs and in that of boilers temporarily disabled and carried as useless freight.

6. *Repairs.* — In warships frequently, and in all vessels at times,

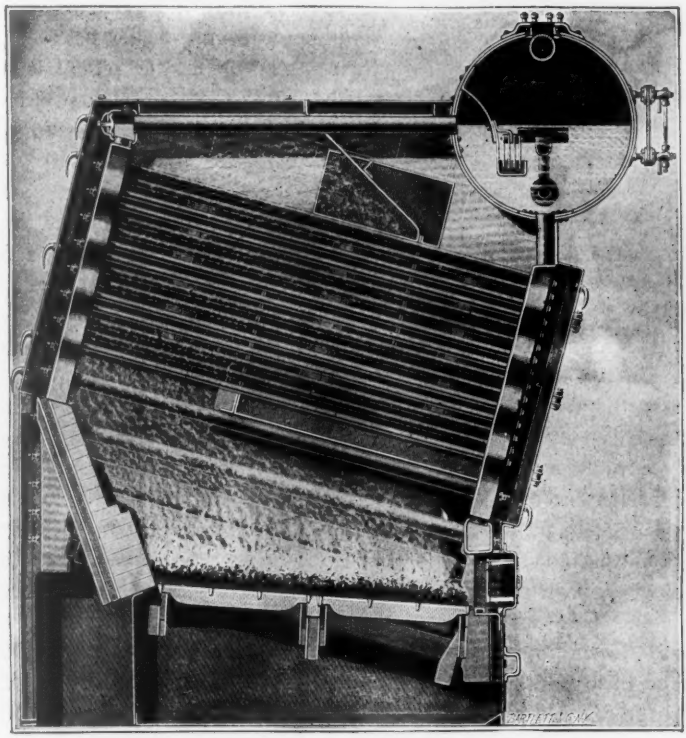


FIG. 2. — "CINCINNATI'S" BOILER. SECTION SHOWING PATH OF GASES

repairs must be made by the ship's force, unaided by the facilities of a repair base. Hence, so far as is possible, the boiler should be so designed as to enable this work to be done readily and quickly. The pressure parts should be accessible, simple, and uniform. Varied forms of tubes, unusual joints, and special fittings of any kind increase, not only the difficulty of repairs, but the number of spare parts to be carried.

Status of the Marine Water-Tube Boiler

The water-tube boiler has in marine service a long history. Fifty years ago the Belleville boiler of that day was installed in the French war vessel *Biche*. It was not until 1888, however, that French naval authorities, the leaders in this advance, took radical action in deciding to replace the cylindrical boiler with those of the Belleville and D'Allest type. From the latter date onward the water-tube boiler has won its way in a progress which has been attended by the production of a large number of designs and by a volume of controversy which, in extent and duration, is probably without equal in the history of marine engineering.

In the course of time the vexed question as to the relative advantages, for general marine service, of many widely differing forms seems to have narrowed down to the consideration of comparatively a few leading boilers. The main principles governing the action and efficiency of these boilers as a class have been discussed. The application of these principles, and hence the status of the marine water-tube boiler, in a practical and successful design will be, perhaps, best understood by the consideration of one of its widely accepted forms.

For this purpose the Babcock and Wilcox marine boiler has some special advantages in the fact that complete data are available. Since 1899 it has been installed in or specified for thirty-seven of our national vessels, from battleships to gunboats. In the papers of United States naval officers on duty as inspectors or as members of trial boards, as published in the *Journal of the American Society of Naval Engineers*, there are given the very full data on which are based the following description of the construction and analysis of the performance of this boiler. The lecturer desires to acknowledge his indebtedness to the editor of the *Journal* and to the Babcock and Wilcox Company for the use of this information and the accompanying illustrations.

The Babcock and Wilcox Marine Boiler: Details of Construction

Modifications for Marine Service. — The marine and the usual land form of this boiler differ in some important respects, the purpose of the changes in the latter form to fit it for sea service being to provide, relatively, much larger areas of grate and heating surface in the same

space. Thus (Figures 2, 4) the furnace in the marine form extends beneath practically the entire length of the tubes, giving the maximum horizontal area of grate, and the diameter of the tubes, excepting in the lower row and at the top of the furnace sides, has been reduced to 2 inches to provide ample heating surface. The steam and water drum is also set transversely to the tubes and at the top and lower end of the bank, thus lessening the height of the boiler; and the firing end is beneath this drum, making the volume of the furnace largest at the rear, where the need of combustion space is greatest. The setting of the land boiler is, of course, replaced by a casing. These changes are in some respects a development of a compact design built originally for land service.

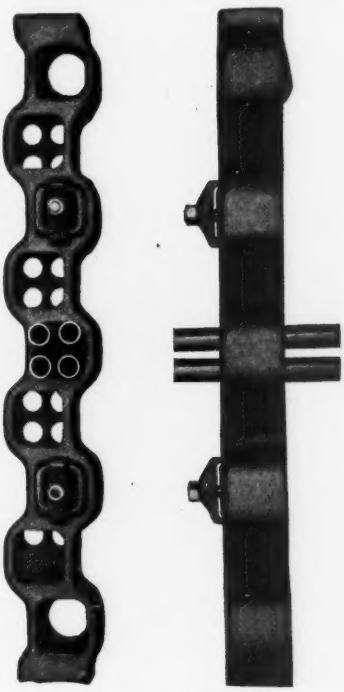


FIG. 3. — FORGED STEEL HEADER, SHOWING HAND-HOLE PLATES

Sectional Elements. — The tube heating surface is divided into sectional elements, each of the latter being composed of vertically staggered groups — four tubes to a group and seven or eight groups to a pair of headers — of 2-inch tubes, with a 4-inch tube at the bottom, all straight. The tubes are inclined usually at an angle of 15° with the horizontal, and are fixed at each end in boxes or headers (Figure 3), the latter being rectangular in section, perpendicular to the tube axes, corrugated vertically to stagger the tube groups, and closed in front of each group and of each 4-inch tube by a hand-hole plate.

The top of each rear header is connected with the steam and water drum by a horizontal circulating tube 4 inches in diameter. Each front header is joined to this drum and to a horizontal cross box, or "mud drum," by nipples of 4-inch tube. In the end elements, which form the sides of the boiler down to the furnace top (Figures 4, 5), the tubes in the outer corrugations are left out in order to give an

approximately straight tube service against which to build the side casing.

All tubes are of seamless, cold-drawn steel. The 2 and 4-inch tubes are 8 and 6 B. W. G., respectively, in thickness. The headers are forged from open-hearth steel plate $\frac{1}{2}$ inch thick. The hand-hole plates are of wrought steel; the joint is made on the inside of the header by a thin gasket between faced seats. Expanded joints are used for all tubes and nipples.

Cross Box. — The cross box, or mud drum, forms a blow-off collector through which the boiler may be drained. It is forged from $\frac{5}{8}$-inch, open-hearth steel plate, is 6 inches square in section, and has hand-holes in the front. It is connected with the front headers and the corner boxes by 4-inch nipples.

Furnace Sides. — The water sides (Figures 2, 4, 5) of the furnace are each composed of four forged steel boxes, 6 inches square in section, and one 4-inch tube, all of which are parallel to the main tubes and enter two vertical corner boxes, one at the front and one at the rear of each side. When the boiler has more than twenty-three sectional elements there are three water sides — two at the furnace sides and one near its middle, the latter water side being connected with a pair of vertical middle boxes similar to the corner boxes.

Thus in each of the boilers of the battleship *Nebraska* there are thirty sections and three water sides. The middle water side divides the grate into two sections, 8 feet $3\frac{1}{4}$ inches and 7 feet $8\frac{1}{4}$ inches in width, respectively. The length of the grate is 7 feet. The water sides and the middle and corner boxes are connected by 4-inch nipples with expanded joints.

Corner and Middle Boxes. — The four corner boxes and the two middle boxes (if used) are forged of the same steel as the cross box; they are 7 inches square outside, $\frac{5}{8}$ inch thick, and have hand-holes in front. They are connected with the water sides, the cross box, and the headers immediately above them by 4-inch nipples with expanded joints, and by the latter with the 4-inch tube of the water side.

A 1-inch plate welded in forms the top of each box, and the bottom is closed in the same way by a $1\frac{1}{4}$-inch plate. From the latter, and made integral with it, a 2-inch stud projects, which fits into a hole in the foundation and is secured by a nut. The corner and middle boxes thus form the supports of the boiler. The plane of their tops is at an angle of 15° with the horizontal.

Drum. — The steam and water drum (Figures 2, 4) provides steam space and water capacity. It is cylindrical with "dished" heads, is 42 inches in diameter inside, and has a length sufficient for the connection of the extreme headers, or practically that of the width of the boiler. Its shell is made of two plates, each the length of the drum, one of such width as to extend through three-fourths of the circumfer-

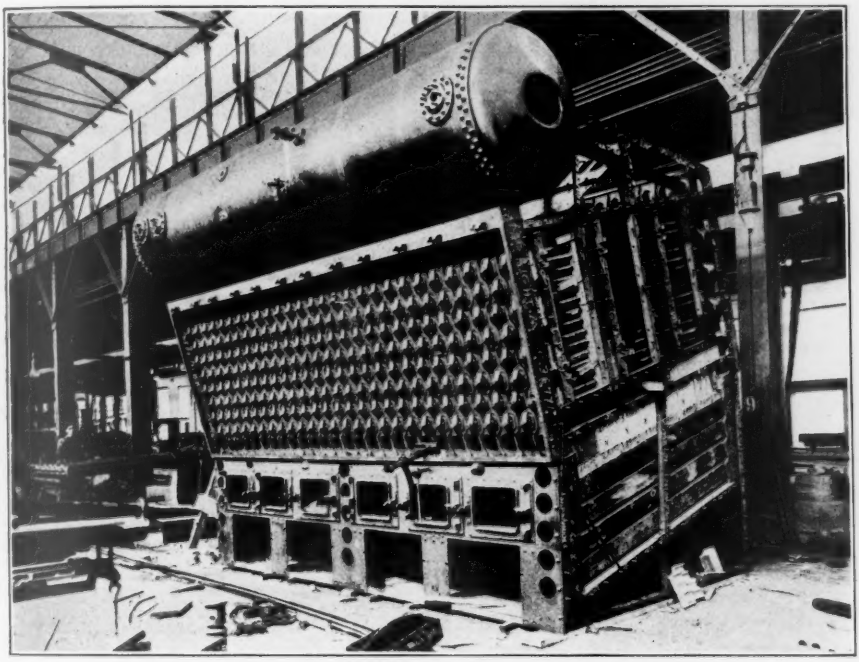


FIG. 4. — ASSEMBLING THE BOILER; READY FOR FIRE TILES AND CASINGS

ence, the other covering the remaining one-fourth. The longitudinal joints are made with double butt straps.

These joints are thus 90° of arc apart, and the drum is so set that the centre line of one coincides with that of the upper nipples of the front headers, while the centre line of the other is identical with that of the circulation tubes which connect the drum and the rear headers. The holes for the tubes and nipples are drilled $4\frac{1}{32}$ inches diameter through the straps and are punched to a diameter of $4\frac{1}{4}$ inches through

the abutting edges of the shell plates. Hence the tubes and nipples when expanded bear only on the metal of the straps, and bulge out slightly in the annular space remaining in the holes in the plates. This construction makes an exceptionally strong joint.

The drumheads are pressed from flat, circular plates 52 inches in diameter. The radius of the spherical "bump," or "dishing," is the same as the drum diameter, 42 inches. Manholes with reënforcing rings are made in the centre of the heads, and the latter are riveted to the shell with double zigzag seams. The butt straps of the shell are held by six rows of rivets, four of which pass through both straps. The thickness of the shell plates and straps is $\frac{21}{32}$ inch; that of the drum head is $\frac{3}{4}$ inch.

The steam openings in the drum are: one for main and auxiliary steam pipes, one for the safety valves, and one for a fitting to which are attached the steam gauge, sentinel valves, and air cock. The water openings are: one for main feed, one for auxiliary feed, one for surface blow, two for each of the two water gauges, and three for the test cocks.

The interior fittings of the drum are: semicircular swash plates to retard the movement of the water when the ship is rolling; perforated baskets for zinc; curved, hinged, and latched baffle plates over the mouths of the circulating tubes; two brass feed pipes, perforated in the upper half, set parallel to, but below, the axis of the drum; a brass dry pipe, perforated in the upper half, connecting the two steam openings; and a steel scum pan of flat, rectangular shape.

Baffles. — The row of 4-inch tubes immediately above the fire is covered with fire brick fitted to the tubes for a distance of about two-thirds of their length from the front, thus roofing the furnace to that extent. A similar baffle is laid horizontally from rear to front on the 4-inch circulating tubes for about one-half their length. From the end of the furnace top a plate baffle extends upward. The gases pass upward from the back of the furnace over the top of this baffle, and then flow downward between it and a similar baffle depending from the horizontal baffle at the top. After passing the lower edge of this second baffle the flames again turn upward, through the tubes and an opening in the top casing back of the drum, to the uptake. The upright baffles thus fall at points which are at about one-third the length of the tubes from their ends, dividing the tube surface into three approximately equal parts.

Supports and Foundations. — The weight of the front ends of the sectional elements is taken by the nipples connecting the front headers with the steam and water drum. The rear ends of the sections are supported by an I-beam resting on brackets bolted to the rear corner boxes. The side and middle sections are stepped into the corner and middle boxes.

The steam and water drum is supported at each end and at the middle by sleeves fitting around the nipples at these points and resting on the tops of the front headers. The drum thus serves as

FIG. 5. — VIEW OF FURNACE FROM BRIDGEWALL, SHOWING ABSENCE OF FIRE BRICK IN SIDE WALLS AND BETWEEN FIRE DOORS

a beam to increase the stiffness of the boiler and to support the front ends of the sections.

The corner and middle boxes rest on chair pieces in the foundations, and each is held in place by a 2-inch stud and nut. The foundations are built up of two 8-inch channel irons, one of which, laid horizontally, flanges upward, forms the base; and the other, set at an angle of 15° with the horizontal, and with the flanges down, forms the top. To the inside flanges of these channel irons there is riveted a ½-inch side plate. Each of the two chair pieces is connected to the foundation base by rivets, to the side plate by two angle irons, and to the top by a steel angle. In each foot of each saddle piece

there is a 1¾-inch hole through which the holding-down bolts pass. In the top of each saddle piece there is a hole 2⅛ inches in diameter, through which the lug in the bottom of the corner box passes; this lug holds the boiler to the foundation. There are three of these foundation pieces in all boilers having middle boxes.

Casing. — The entire boiler, except the drum, is enclosed in an air-tight casing (Figure 7), consisting — from the inside outward — of light fire tiles, ¼-inch asbestos mill board, and 2-inch block magnesia, backed with galvanized steel plate ⅛ inch thick. The fire tiles, as shown in Figure 6 by the interior of the cleaning doors, are shaped to fit the sides of the tubes and the spaces between them. All cracks between headers, side boxes, etc., are calked with rope asbestos. The outside plating is held in place by edge straps bolted to the casing frame, and is thus readily removable. The latter is built of angles, and is secured to the boiler foundation by straps held in place by studs and nuts, the studs being screwed into the flanges of the angles forming the framework. The removal of the casing to expose the tubes and baffles is the work of a few minutes.

Cleaning Openings. — As shown in Figure 6, there are three upright doors in the side of the casing, one opposite each division of the heating surface formed by the upright baffles. These three doors are swung on side hinges and may readily be opened. Below them there are two narrow horizontal doors (Figure 7) held in place by latches, which enable the soot to be cleaned from the baffle forming the furnace top, and above them and just back of the drum there is another latched door (Figure 6), which gives access to the space above the inclined tubes.

These six doors provide ample means of cleaning the heating surfaces when the boiler is not in use if sufficient room be left at the side of the boiler to permit the use of the soot hoe and tube brushes. The soot may be also almost entirely removed from the tubes while under way by means of an air jet or steam lance inserted through the five (or seven) small openings made on the vertical centre line of each of the three main "dusting" doors. These holes are closed by a sliding shutter; they serve also as peepholes to observe the extent of the flame.

Fire Front and Doors. — The fire fronts of the boiler are of wrought steel and contain fire and ash doors. The fire doors are made of ½-inch steel plate, accurately fitted to a flanged door frame of the

same material; these doors are lined with cast iron. The ash doors are also of wrought steel and the ash pans of galvanized steel.

Tube Doors. — The front and rear tube doors are made of steel plate riveted to a bar steel frame and lined with non-conducting material, backed by sheet copper secured by rivets. The frames of the rear tube doors are attached to the I-beam which supports the rear ends of the sections.

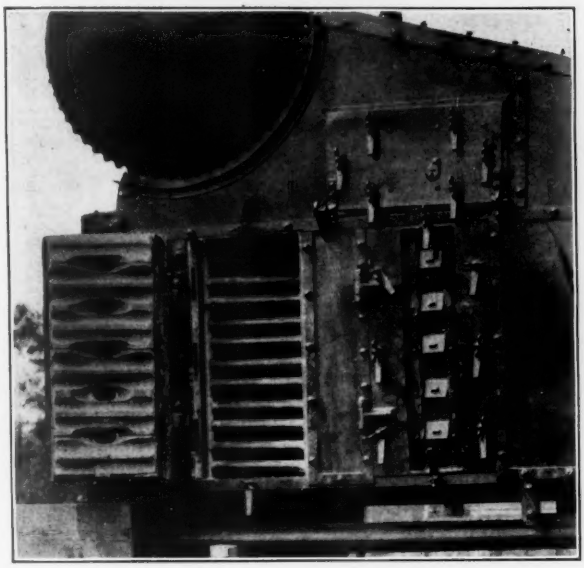


FIG. 6. — CLEANING DOORS

Centre of Gravity of Boiler. — The centre of gravity of the boiler lies, approximately, on a horizontal line passing through the intersection of two diagonal lines, one drawn on the side elevation of the boiler from the centre of the drum to the lowest point of the foundation at the back, and the other from the highest point of the rear header to the base of the foundation at the front. The centre of gravity is thus about 6 feet above the base. When the boiler is filled this distance is increased slightly.

CHARACTERISTICS AND CONSTRUCTION

Sectional Construction. — The Babcock and Wilcox boiler is of sectional construction, the tube heating surface being divided into elements, each independent of the others. Each element is composed of its generating tubes, one front and one rear header, and a circulating tube. Such a system gives freedom for unequal expansion in rapid steam raising and for contraction due to sudden cooling. All flat-stayed surfaces are dispensed with by the use of the headers.

A marked advantage of the sectional system is that the boiler may be assembled on shipboard, thus obviating any cutting of the decks in reboilering. At the outbreak of the Spanish-American War three of the old single-turreted monitors were thus reboilered, the parts being passed below through the 7-foot armored smoke pipes. Two of the vessels were ready for steam in thirty days and the third in forty-two days after the work was ordered.

Size of Units. — An objection frequently urged in the past against the water-tube boiler in general was that the size of its units was smaller, and hence their number for the same total power greater, than those of the marine cylindrical boiler, with a consequent increase in the number of valves and fittings and in the extent and complexity of the piping.

Such objections no longer apply to this boiler, since its system of construction makes possible as great an increase in width as is permitted by the efficient use of the lance from the sides in blowing soot from the tubes. In the table below are given average data from the *Alabama* class of battleships — the last vessels built with cylindrical boilers for the United States Navy — and similar data from the most recent trial of a battleship fitted with the Babcock and Wilcox boiler.

	I. H. P.	Boilers.	H. P. per unit.
Battleship *Alabama*	12,291	8 S. E. cyl.	1,536
Battleship *Louisiana* . . .	21,350	12. B. W.	1,779

Weight Saving. — The economy in weight from the use of water-tube boilers lies in both that of the boiler and that of its contained water. With regard to the boiler (*dry*) the following average data refer to the *Alabama* class, as built, and their total I. H. P. on con-

tract trials, and to the battleship *Nebraska* (12 B. W.), the power being the designed I. H. P. and the weight that estimated from the weight of one boiler as built.

	I. H. P.	Boilers: Weight (Dry), Pounds.	
		Total.	Per I. H. P.
Battleship *Alabama*	12,291	905,525	73.67
Battleship *Nebraska* . . .	19,000	1,165,596	61.35

There is thus a weight saving in the boilers (dry) of 16.9 per cent., based on the weight per I. H. P.

The comparison, including the weight of the contained water, is:

	Weights, Pounds.		
	Water, total.	Water per I. H. P.	Boilers (wet) per I. H. P.
Alabama	345,342	28.09	101.76
Nebraska	234,384	12.34	73.69

which shows a saving per I. H. P. of 56.1 per cent. in the weight of contained water, and of 27.6 per cent. in that of boilers and water combined.

The comparison, with regard to grate and heating surface, is for the weights of boilers and water combined:

	Boilers, Wet. Pounds per Square Foot of	
	Grate surface.	Heating surface.
Alabama	1,855	57.5
Nebraska	1,044	24.9

The weight of contained water is that of the amount at 4 inches above the highest heating surface in the cylindrical boiler and at the level of the centre of the drum in the Babcock and Wilcox boiler. The *Nebraska* weights were found with the water at 62° F.

The working pressure of these boilers is for the *Alabama* class

180 pounds gauge and for the *Nebraska* class 275 pounds gauge. Since the advanced pressure gives greater steam economy and reduces the machinery weights per I. H. P., it is evident that a just comparison between the cylindrical and water-tube types is that at the working pressure which the latter makes practicable. The following data — pre-

FIG. 7. — BOILER COMPLETE, SHOWING CASING

pared some years ago at the Bureau of Steam Engineering, United States Navy — show this relation with regard to a proposed naval installation of 16,500 I. H. P. at 250 pounds working pressure. The comparison was made between a plant consisting of six double-ended and two single-ended Scotch boilers and one of twelve Babcock and Wilcox boilers.

	Cylindrical.	Babcock and Wilcox.
Steam pressure, gauge, pounds	250	250
Weights, boilers and fittings, tons	739	462
Weights, water in boilers, tons	252	105
Weights, boilers and water, tons	991	567
Weights, all machinery, including stores, tons	2,045	1,630

It will be seen that the use of cylindrical boilers would have increased the weights of boilers and water 74.8 per cent. and the total machinery weights 25.5 per cent. However, the cylindrical boiler at that pressure was a practical impossibility. The boilers estimated upon for this comparison were 15 feet $5\frac{1}{8}$ inches in diameter, with shell sheets $1\frac{5}{16}\frac{9}{4}$ inches thick, braces 3 inches in diameter, and furnaces but 2 feet 9 inches in diameter. Were the cylindrical boiler the only reliance, the road to higher working pressures would be blocked.

Floor Space. — The inclination of the tubes of the Babcock and Wilcox boiler is sufficient to assure a positive circulation under all conditions of rolling and pitching. Hence it may be installed with its tubes either fore and aft or athwartship. The latter method of installation — which is impossible for boilers of feeble or uncertain circulation — is that used with the Babcock and Wilcox boilers on the United States cruisers *Chicago*, *Atlanta*, *Cincinnati*, and *Raleigh*, and on forty-five merchant steamers on the Great Lakes. Since its form is approximately rectangular throughout, it is well fitted for utilization of a limited space.

The ratio of floor space (horizontal projection) to grate areas is, in general, about 1.9, as compared with 2.1 for the cylindrical boiler. With the larger units this ratio is somewhat more favorable to the Babcock and Wilcox boiler. Thus the data for the protected cruiser *Charleston* are:

I. H. P., all machinery	27,506.0
Boilers	16 B. W.
H. P. per boiler unit	1,719.0
Floor space, one boiler, square feet	138.2
Grate surface, one boiler, square feet	87.5
Floor space ÷ grate surface	1.58

The extreme vertical height of the boiler is, roughly, about 20 per cent. greater than its length. The space between the sides of adjacent boilers required for the use of cleaning tools is about 5 feet.

Tube and Plate Heating Surfaces. — General proportions as to these are shown by the following data, which refer to the *Illinois* (eight single-ended Scotch boilers), of the *Alabama* class, and to the gunboat *Dubuque* (two Babcock and Wilcox boilers).

Illinois

Heating surface, one boiler:	
Tubes, square feet	2,273.7
Furnaces (four), square feet	176.4
Combustion chambers (two), square feet	256.0
Total	2,706.1
Tube heating surface, per cent.	84

Dubuque

Heating surface, one boiler:	
Tubes, square feet	1,970.7
Side boxes and drum, square feet	108.8
Total	2,079.5
Tube heating surface, per cent.	95

I. H. P. per Square Foot of Grate and Heating Surface. — The following data refer to the contract trials of the *Wisconsin* (cylindrical), of the *Alabama* class, the protected cruiser *Charleston* (Babcock and Wilcox), previously noted, and the protected cruiser *Galveston* (six Babcock and Wilcox boilers; I. H. P., 5,178.5, all machinery).

	Wisconsin.	*Charleston.*	*Galveston.*
Air pressure in fire room, inches of water	0.924	2.48	2.00
Coal per hour per square foot G. S., pounds	37.2	40.9	33.41
Coal per hour per square foot H. S., pounds	1.123	0.895	0.758
I. H. P. (total) per square foot G. S.	19.7	19.65	17.26
I. H. P. (total) per square foot H. S.	0.5946	0.4298	0.3923

Ratio of Heating to Grate Surface. — In the three vessels, as above:

	H. S. ÷ G. S.
Wisconsin	33.13
Charleston	45.71
Galveston	44.00

In the cylindrical boiler the length of the grate is limited by the relatively small diameter of the furnace and by the draught. This restriction does not apply to the water-tube boiler. In the three vessels, as above, the lengths of the grate are, respectively, 6 feet $1\frac{7}{8}$ inches, 7 feet, and 6 feet 6 inches. The percentage of air space in naval grates is usually 43.

Furnace Volume; Combustion Gas Passages. — In the *Illinois* (cylindrical), of the *Alabama* class, the ratio of the volume of the furnaces and combustion chambers above the grates to the grate surface is 4.07. The average height of the Babcock and Wilcox furnace is about 2 feet 9 inches, making this ratio for the furnace alone 2.75. With moderate forced draught, the flame from the furnace generally reaches as far as the middle of the second "pass." On the trial of the *Denver* (*Galveston* class), with 0.9-inch air pressure, the flame went into the third pass.

In the *Illinois* (cylindrical) the ratio of the area through the tubes to the grate surface is 0.16. The *Dubuque* (Babcock and Wilcox), previously noted, on her contract trial burned 19.08 pounds of coal per square foot of grate surface with an air pressure in fire rooms of 0.125 inches of water. The ratio of heating to grate surface is 41.68. The grate surface is 49.9 square feet. The area for the passage of the gases of combustion is, in

First section	10.36 square feet
Second section	10.2 square feet
Third section	8.6 square feet
Uptake section	8.2 square feet

giving ratios of these areas to grate surface of 0.208, 0.204, 0.172, and 0.164, respectively.

The height of the smoke pipes (two) above the grate is in this

case 60.33 feet. Each is 37 inches in diameter, with a sectional area of 7.4666 square feet, giving a ratio of smoke pipe area to grate surface of 0.149.

Steam Space and Steam Liberating Surface. — Too small a steam space causes priming, the water being carried off as spray with the steam; too large a space increases the radiation losses. In comparing the cylindrical and the Babcock and Wilcox boilers in this respect, and under similar conditions otherwise, the relative volumes per pound of the steam at the working pressures should be considered. The following data relate to the *Illinois* (cylindrical) and the *Galveston* (Babcock and Wilcox), both referred to previously.

	Illinois.	*Galveston.*
Steam pressure, pounds, gauge	177.0	264.0
I. H. P. per boiler	1,612.0	863.0
Heating surface, one boiler, square feet	2,706.1	2,200.0
Grate surface, one boiler, square feet	85.6	60.0
Steam space, one boiler, with water 4 inches above highest heating surface, cubic feet,	355.0	. .
Steam space above plane of centres of circulating tubes and drum, cubic feet	. .	50.44
Steam space per I. H. P., cubic feet	0.22	0.058
Steam space per square foot heating surface, cubic feet	0.13	0.023
Steam space per square foot grate surface, cubic feet	4.14	1.01

The steam space per I. H. P. of the Babcock and Wilcox boiler is thus about one-fourth that of the cylindrical boiler cited, with, in this respect, a marked reduction in the losses by radiation.

At the water levels given above:

	Illinois.	*Galveston.*
Steam liberating surface, square feet	116	72.14
Liberating surface per I. H. P., square feet	0.072	0.084
Liberating surface per square foot heating surface, square feet	0.043	0.033
Liberating surface per square foot grate surface, square feet	1.355	1.44

It will be seen that the steam liberating surface is ample. With regard to this matter the Babcock and Wilcox Company report[1] the following experiment (Figure 8):

[1] Marine Steam, Babcock & Wilcox Company, p. 100.

"A peephole, filled with a stout piece of glass, was made in each drumhead opposite the space between the return circulating tubes and the baffle plate. By means of an electric arc light placed at one eye-piece the interior of the drum was illuminated and the discharge of each of the circulating tubes distinctly seen.

"When the boiler was steaming rapidly, with ¾-inch air blast in the ash pit, the observations clearly showed that each of the circulating tubes was discharging against the baffle plate with considerable velocity a stream of solid water that filled the tube for half its diameter.

"There was no spray of mist whatever, showing conclusively that the steam had entirely separated from the water during its passage

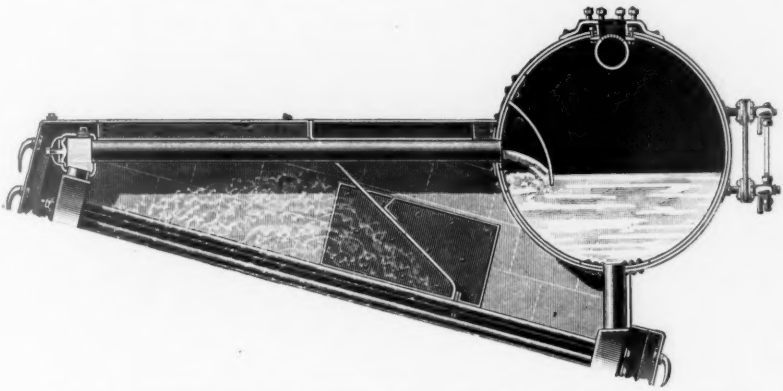


FIG. 8. — PARTIAL VERTICAL SECTION, SHOWING STEAM-LIBERATING ACTION

through the circulating tubes, which in this boiler were only 50 inches long by 4 inches in diameter. As a matter of fact, the actual steam-liberating surface required for the entire boiler was less than that contained in the circulating tubes, which amounted to about 15 square feet, or 1 square foot to every 100 square feet of heating surface in the boiler."

Quality of Steam. — This boiler, under the conditions of a shore test, furnishes steam which may be considered as perfectly dry. This is true also in a smooth sea when there is neither oil nor salt in the feed. In tests made by boards of United States naval officers the average amount of moisture found in the steam was: in the *Alert* boiler, seven-tenths of one per cent.; *Cincinnati* boiler, six-tenths of one per cent.; *Nebraska* boiler, five-tenths of one per cent.

One reason for this is that the steam-liberating surface is relatively large, being .084 square foot per I. H. P. in the *Galveston*, whose steam pressure on trial was 264 pounds gauge, as compared with .072 square foot on the *Illinois*, with a corresponding pressure of 177 pounds. Again, the normal water level is in the plane of the centres of the circulating tubes, as shown in Figure 8. Hence time is an important factor, since from the instant of entrance into the circulating tubes and during passage through them steam may free itself. Finally, the drum is not exposed to great heat, and therefore the water is not agitated in any way except by the rolling and pitching of the vessel. The "swash plates" fitted in the drum act to minimize the effect of the motion of the hull.

Water Endurance. — The time taken to evaporate the water from the normal water level to the "danger line," *i. e.*, the level of the highest heating surface, is important, since the feed may at times fail through accident or neglect. While accurate data on this point are not at present available to the lecturer, the following approximations are close enough to serve.

In the boilers of the *Illinois* (cylindrical) previously noted the gross volume, including combustion chamber staying, between the two levels, as above, is about 38.3 cubic feet. In the boilers of the *Nebraska* (Babcock and Wilcox) the first gauge cock is located above but close to the level of the highest point of the generating tubes. This level — assuming that the circulating tubes and drum are never exposed to great heat — may be taken as corresponding with the tops of the combustion chambers in the cylindrical boiler, although the two cases are not wholly the same in the exclusion of this heating surface and in the usual location of the lowest gauge cock in the cylindrical type.

In the test of the *Nebraska's* boiler it was found that to raise the water level from the first gauge cock to the centre of the drum required 2,619 pounds of water at 62° F. This corresponds with a volume of 42 cubic feet.

Taking the horse power of the main engines only:

	Illinois.	*Nebraska.*
I. H. P., main engines	12,647	19,000
Number of boilers	8	12
I. H. P. per boiler	1,581	1,583
Water space from normal level to "danger line," cubic feet	38.3	42
Water space from normal level to "danger line," per boiler H. P., cubic feet	0.0242	0.0265

The working pressure of the cylindrical boiler is 175 pounds gauge and that of the Babcock and Wilcox boiler 275 pounds gauge, with — taking Dr. Thurston's figures — weights of water per cubic foot of 54.5 and 53.1 pounds, respectively. Hence the water-tube boiler at working pressure will contain a less weight of water per cubic foot of space. On the other hand, the main engines at the higher working pressure should use a smaller weight of steam per I. H. P. In any event, it is clear that, with the assumptions as above, the Babcock and Wilcox boiler closely approaches in water endurance the marine cylindrical boiler cited.

Speed of Circulation. — The factors combining to produce circulation in this boiler have been noted. Mr. George H. Babcock, in a lecture at Cornell University in February, 1890, gave the following interesting discussion of the approximate speed of circulation in land boilers of this type:

"In such a construction the circulation is a function of the difference in density of the two columns. Its velocity is measured by the well-known Torricellian formula, $V^2 = 2gh$, or, approximately, $V = 8\sqrt{h}$, h being measured in terms of the lighter fluid. This velocity will increase until the rising column becomes all steam, but the quantity of weight circulated will attain a maximum when the density of the mingled steam and water in the rising column becomes one-half that of the solid water in the descending column, which is nearly coincident with the condition of half steam and half water, the weight of the steam being very slight compared to that of the water.

"Let us take, for example, one of the 240-horse-power Babcock and Wilcox boilers here in the university. The height of the columns may be taken as $4\frac{1}{2}$ feet, measuring from the surface of the water to about the centre of the bundle of tubes over the fire, and the head would be equal to this height at the maximum of circulation. We should, therefore, have a velocity of $8\sqrt{4.5} = 16.97$ — say, 17 feet per second.

"There are in this boiler fourteen sections, each having a 4-inch tube opening into the drum, the area of which (inside) is 11 square inches, the fourteen aggregating 154 square inches, or 1.07 square feet. This multiplied by the velocity, 16.97 feet, gives 18.16 cubic feet of mingled steam and water discharged per second, one-half of which, or 9.08 cubic feet, is steam. Assuming this steam to be at 100 pounds gauge pressure, it will weigh 0.258 pound per cubic foot. Hence 2.34

pounds of steam will be discharged per second and 8,433 pounds per hour. Dividing this by thirty, the number of pounds representing a boiler horse power, we get 281.1 horse power — about 17 per cent. in excess of the rated power of the boiler.

"The water at the temperature of steam at 100 pounds pressure weighs 56 pounds per cubic foot, and the steam 0.258 pound, so that the steam forms but $\frac{1}{218}$ part of the mixture by weight; and consequently each particle of water will make 218 circuits before being evaporated when working at this capacity and circulating the maximum weight of water through the tubes.

. . . "In designing boilers of this style, it is necessary to guard against having the uptake at the upper end of the tubes (the rear header in the marine Babcock and Wilcox) too large, for if sufficiently large to allow downward currents therein the whole effect of the rising column in increasing the circulation in the tubes is nullified. This will readily be seen if we consider the uptake very large, when the only head-producing circulation in the tubes will be that due to the inclination of each tube taken by itself. The objection is only overcome when the uptake is so small as to be entirely filled with the ascending current of mingled steam and water. It is also necessary that this uptake should be practically direct, and it should not be composed of frequent enlargements and contractions."[1]

The theoretical circulation, as calculated above, is, of course, affected by bends and the friction of tubes and passages. In the later forms of the marine Babcock and Wilcox boiler the length of the 2-inch tubes is 48 diameters. In the bottom row, however, where the circulation is most vigorous, the diameter is 4 inches, giving a tube length of 24 diameters, which is the theoretically correct length, according to the London *Engineer*.

Baffling. — Assuming fair water circulation — which in most cases may readily be obtained — an effective system of baffling the gases is vital to the efficiency of the water-tube boiler at high rates of combustion, since it prolongs the duration of contact of the gases and heating surfaces, and hence increases the interval for heat absorption by the water. Such a system is frequently difficult to design and apply. Many water-tube boilers, in fact, fail markedly in this respect.

In the Babcock and Wilcox marine boiler the gas currents, in the

[1] Steam, Babcock & Wilcox Company, 1902, p. 21.

first place, meet the tubes at right angles; secondly, the tubes are staggered vertically. Owing to these two conditions the gas currents are broken and their flow impeded. Mr. Watt, whose experiments have been referred to previously, found that tubes placed in vertical rows gave a maximum evaporation which was but 82 per cent. of that shown by tubes staggered as above.

Again, the space between the tubes is divided into three sections, or "passes," as has been shown, by two baffles set perpendicularly to the tube axes, so that the gases are forced to cross the tubes three times on their way from the furnace to the uptake. This circuitous route gives them a travel of about 16 feet before exit, which distance, it is stated, is longer than the similar travel in any marine water-tube boiler, and is, in any event, sufficient to obtain fair and sustained efficiency at the higher rates of combustion.

Gas Temperatures. — In June, 1900, tests were made by a naval board upon a Babcock and Wilcox boiler built for the United States cruiser *Cincinnati*. The grate surface was 63.25 square feet, the heating surface 2,640 square feet, and the boiler was fitted with an air heater located at the base of the uptake. In the tests noted below the air heater was not used. The temperatures of the gases were found at various locations by the melting points of different metals. The system of baffling was that which has just been described. The "fractions of travel" represent portions of the total travel of the gases from the beginning to the end of the tubes in crossing the latter three times. The tests were:

1. Full grate; coal per square foot grate per hour, 35.08 pounds; water per square foot heating surface from and at 212°, 8.78 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{9}{12}$	1,160°
$\frac{11}{12}$	842°
$\frac{22}{12}$	780°
$\frac{41}{12}$	625°
Flue temperature	601°

2. Length of grate shortened, making grate surface 52 square feet; coal per square foot grate surface per hour, 50.38 pounds; water per square foot heating surface from and at 212°, 10.07 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{7}{42}$	1,160°
$\frac{11}{42}$	852°
$\frac{26}{42}$	780°
$\frac{41}{42}$	650°
Flue temperature	640°

3. Full grate, coal per square foot grate surface per hour, 59.2 pounds; water per square foot heating surface from and at 212°, 13.68 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{18}{42}$	1,160°
$\frac{35}{42}$	870°
Flue temperature	850°

In test No. 1, which is nearest to the normal steaming of this boiler, there is a very marked fall of temperature in passing upward from 64 per cent. to 80 per cent. of the height of the first pass; from the latter point to the end of the tube surface the fall is gradual, almost rectilineal when plotted. The furnace temperature and that of the tubes to the first point noted were not observed.

Sir A. J. Durston[1] discusses in this respect a test of a return five-tubular marine boiler, worked at its normal capacity, the consumption of coal being 17 pounds per square foot grate surface. The temperature in the combustion chamber was 1,644° F.; just inside the tube, 1,550°; in tube, 1 inch from combustion chamber, 1,466°; 2 inches, 1,426°; at end of tube, 887°; in smoke box, 782°. About $\frac{2}{11}$ of the total fall of temperature took place in the first 2 inches of the tube, after which the fall was fairly evenly distributed throughout its length.

Steam Raising. — In the *Cincinnati* tests fires were started on a cold boiler, lightwood being used and the blower running (closed stokehold system). Steam formed in five minutes, and in twelve minutes forty seconds had reached a pressure of 215 pounds gauge. To raise steam in the cylindrical boiler, without special appliances for circulation and without endangering its complex structure, requires from five to ten hours, depending mainly upon whether the boiler is single or double ended.

Rapidity in raising steam, which is a characteristic of the water-tube

[1] Transactions of the Institute of Naval Architects, March 23, 1893.

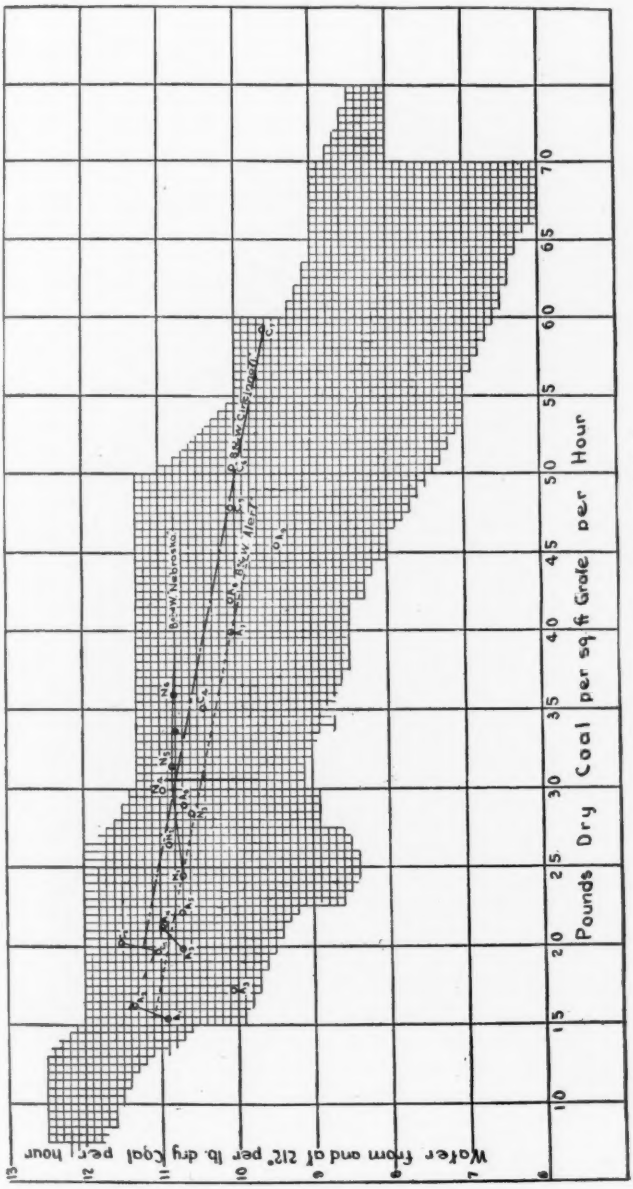


FIG. 9. — EVAPORATIVE EFFICIENCY

boiler in general, is, in navies, of the greatest tactical value. It is a well-known fact that owing to the inherent defect in this respect of the cylindrical boiler our fleet was, as a whole, unprepared for steaming at full speed when Cervera's squadron made its dash from Santiago. If the ships had been fitted with water-tube boilers the difficult problem which confronted the fleet in maintaining its preparedness for immediate action at full speed would have been solved. As it was, banked fires under the full installation required a heavy expenditure of fuel; coaling at sea off Santiago was often impossible, and the retirement of a ship to Santiago for that purpose meant her absence from a possible battle line.

Rapidity in raising steam is sometimes a factor of much importance in the merchant service also. If, as on the Great Lakes, the unloading facilities are such that the stay of large freight steamers in port may be limited to about six hours, only the water-tube boiler will prevent unnecessary detention, since in that restricted period the cylindrical boiler would scarcely have time to cool, leaving its cleaning, repairs, and slow steam raising yet to be done.

Evaporative Efficiency.— Three exhaustive tests of Babcock and Wilcox marine boilers, built for the United States Navy, have been made by naval boards. These tests are:

1. *Alert's* boiler, April, 1899. Heating surface, 2,125 square feet; grate surface, 48 square feet.

2. *Cincinnati's* boiler, June, 1900. Heating surface, 2,640 square feet; grate surface, 63.25 square feet.

3. *Nebraska's* boiler, December, 1903. Heating surface, 4,682 square feet; grate surface, 111.72 square feet.

For complete data of these tests see *Journal of American Society of Naval Engineers*, Volume XI, No. 2; Volume XII, No. 4; Volume XVI, No. 1. The evaporative results, as plotted by Lieutenant Commander Bryan, are given in Figure 9, the abscissæ being pounds dry coal per square foot grate surface per hour, and the ordinates the pounds water evaporated from and at 212° per pound dry coal per hour, both as given in the table on page 153.

These three tests of the Babcock and Wilcox marine boiler represent successive designs showing the success of the efforts to increase its efficiency by baffling, the general form of the latter being, however, the same in all and that which has been described previously. The results are not strictly comparative, since in both the *Alert* and

Type of boiler.		Duration of test, hours.	Draft in ash pits, inches of water.	Coal per sq. ft. of grate, pounds.	Water from and at 212° per pound dry coal.	Temperature gases in base smoke pipe.	Steam pressure per gauge, pounds.	No. of point on curve,	Remarks.
					Pounds	F.°			
Babcock and Wilcox, *Nebraska* Test made on shore	G. S. = 141.72 sq. ft. H. S. = 4,682 sq. ft.	7	. .	24.48	10.70	673.0	. .	N_1	Closed ash pit
	Weight, dry . . . . . 97,133 pounds	8	. .	26.46	10.89	650.0	. .	N_2	Closed ash pit
	water . . . . . 19,532 pounds	8	. .	28.56	10.57	680.0	. .	N_3	Closed fire room
		7½	. .	29.99	10.97	688.0	. .	N_4	Closed fire room
	wet . . . . . 116,665 pounds	8	. .	31.46	10.83	716.0	. .	N_5	Closed ash pit
		5	. .	36.09	10.80	693.0	. .	N_6	Closed fire room
Babcock and Wilcox, *Cincinnati* Tests made on shore	G. S. = 6,325 sq. ft. H. S. = 2,640 sq. ft.	8	.25	19.61	11.03	466.0	209.3	C_1	. . . .
	* Reduced grate = 52 sq. ft.	8	.107	20.19	11.51	493.0	206.6	C_2	Draught heated to 458°
	Weight, dry . . . . . 53,304 pounds	6	1.42	33.51	10.49	608.6	210.6	C_3	Draught heated to 569°
	water . . . . . 9,498 pounds	6	1.37	35.08	10.41	570.6	207.4	C_4	. . . .
		4	1.45	47.81	10.17	637.0	209.8	C_5	Reduced grate.* Draught heated to 674°
	wet . . . . . 62,802 pounds	4	1.37	50.38	10.14	640.0	213.6	C_6	Reduced grate*
		3½	1.685	59.23	9.63	900.0	210.8	C_7	. . . .
Babcock and Wilcox, *Alert* Test on shore	G. S. = 48 sq. ft. H. S. = 2,125 sq. ft.	. .	.23	15.35	10.93	. .	. .	A_1	. . . .
	Weight, dry . . . . . 46,110 pounds	. .	.26	16.16	11.33	. .	. .	A_2	. . . .
	water . . . . . 7,660 pounds	. .	.43	19.85	10.72	. .	. .	A_3	. . . .
		. .	.61	21.14	10.97	. .	. .	A_4	. . . .
	wet . . . . . 53,770 pounds	. .	.55	22.09	10.70	. .	. .	A_5	. . . .
		6	1.14	28.82	10.66	521.0	218.0	A_6	Anthracite coal
		6	1.82	39.93	10.05	581.0	. .	A_7	Draught heated. Jet and blower draught
		6	1.91	41.88	10.06	567.0	220.0	A_8	Draught heated
		6	1.93	45.39	9.41	619.0	219.0	A_9	Draught heated

Cincinnati tests heated draught and different coals were used in some cases. The *Nebraska's* boiler was baffled to obtain certain results, it being calculated to burn a little over 30 pounds per square foot grate surface at a fire-room pressure of 1 inch of water.

Differences in other respects are, however, overshadowed by the one source of error which cannot be eliminated, viz., the quality of the firing. In view of this consideration the test results may be compared without material error. The *Nebraska's* boiler showed a sustained evaporative efficiency through a fairly wide range of coal consumption. In burning from 25.52 to 37.88 pounds dry coal per square foot grate surface per hour, the evaporation ranged between 10.57 and 10.97 pounds water from and at 212° per pound coal. Both the *Cincinnati* and *Alert* tests show a steady but moderate and uniform fall in evaporation, with increased coal consumption. The influence of a good system of baffling is marked in these results.

With regard to the evaporation per hour per square foot of heating and grate surface, the latest tests — those of the *Nebraska* — give:

Dry coal per square foot grate surface, pounds	25.52	31.50	37.88
Dry coal per square foot heating surface, pounds	0.609	0.752	0.904
Water from and at 212° per square foot grate surface, pounds	273.2	346.1	409.2
Water from and at 212° per square foot heating surface, pounds	6.52	8.26	9.77

Boiler Efficiency. — On the basis of the consumption of dry coal per hour per square foot grate surface, the efficiencies of the boilers were in the

	Coal.	Efficiency.
Alert	19.85	70.65
Alert	28.82	74.60
Alert	41.88	67.30
Alert	45.39	61.95
Cincinnati	19.61	73.1
Cincinnati	20.19	74.3
Cincinnati	33.51	70.6
Cincinnati	35.08	70.1
Cincinnati	50.38	67.5
Cincinnati	47.81	69.0
Cincinnati	59.23	63.4

The report of June, 1904, of the British Committee on Naval Boilers states:

"The best results obtained with the Babcock and Wilcox boilers of the *Hermes* were during the trials of the furnace-gas baffling, the boilers in the middle boiler room, with vertical baffles and a forced air supply over the fires, giving the high efficiency of 81 per cent. on a thirty hours' trial when 20 pounds of coal were burned per square foot of fire grate per hour, and an efficiency of 77.8 per cent. on a twenty-nine hours' trial when burning 27 pounds per square foot, these rates of combustion corresponding to the ordinary rate of steaming and to the full power of the boilers, respectively."

Efficiency of Combustion. — In the tests of the *Nebraska's* boiler, No. 1 was made with closed ash pit, ½ inch draught; No. 5 with closed fire room and 1 inch draught; No. 6 with closed fire room and 1½ inches draught. Other data of these three tests are:

	Test No.		
	1	5	6
Dry coal per hour per square foot grate surface, pounds	25.52	31.5	37.88
Flue gases CO_2	12.7	13.25	9.95
Flue gases O	5.27	6.15	9.40
Flue gases CO	0.8	0.0	0.0

Coal per I. H. P. — The "pounds coal per I. H. P." is a time-honored although scarcely accurate measure of boiler performance in marine trials. It assumes, in such comparisons, the same quality of coal and skill in firing, the same losses in the steam pipes, and the same weight of steam of the same heat value as expended per I. H. P. through installations which may vary somewhat widely in their character. The following data relate to three of the last battleships with cylindrical boilers built for the United States Navy, and to the latest published trials of ships with Babcock and Wilcox boilers constructed for that service.

	Boilers.	Coal, Pounds	I. H. P.
		Per I. H. P., all machinery.	Per square foot grate surface.
Battleship *Kearsarge*	Cylindrical	2.36	17.45
Battleship *Kentucky*	"	2.63	18.00
Battleship *Wisconsin*	"	1.88 (Welsh coal)	19.70
Battleship *Louisiana*	Babcock and Wilcox	1.973	19.46
Armored cruiser *West Virginia* . .	" " "	3.037	16.54
Armored cruiser *Maryland*	" " "	2.849	17.79
Protected cruiser *Charleston* . . .	" " "	2.08	19.65
Protected cruiser *Chattanooga* . .	" " "	1.97	17.99
Protected cruiser *Galveston*	" " "	1.935	17.26
Protected cruiser *Denver*	" " "	2.36	20.675
Protected cruiser *Tacoma*	" " "	2.16	18.08
Protected cruiser *Cleveland*	" " "	1.995	15.616
Gunboat *Paducah*	" " "	2.129	12.705
Gunboat *Dubuque*	" " "	1.559	12.228

The three ships with cylindrical boilers average 2.29 pounds coal per I. H. P.; the eleven with Babcock and Wilcox boilers average 2.186 pounds.

When, as in relatively few cases, a single installation is composed of both cylindrical and water-tube boilers practically all uncertainties in this comparison are removed. *Engineering*, London, April 28, 1905, Volume LXXIX, page 550, says:

"One of the King Edward VII battleships, which has the combination system, was ordered to run four trials of eight hours' duration in order to test the comparative evaporation of the same proportion of cylindrical and Babcock and Wilcox boilers. The first trial was with Babcock and Wilcox boilers, equal to one-fifth total power, and the second with cylindrical boilers, also equal to one-fifth of the total power. It was found that whereas the former gave 3759 I. H. P., the tank boilers gave only 3634 I. H. P.; the coal consumption was 1.74 lb. and 1.8 lb. per I. H. P. per hour, respectively. The third trial was with all the cylindrical boilers working under full-power trial conditions, under an air pressure not exceeding 1 in.; while the fourth trial was with an equal proportion of boilers of the Babcock and Wilcox type, burning an equal amount of coal to that used by the cylindrical boilers in the third trial, and run so as to attain as high a power as possible.

The cylindrical boilers were supposed, when the design was prepared, to be equal to two-fifths of the full power — namely, 7200 I. H. P.; but on this special trial, when worked at an air pressure of 0.96 in., it was found that the total power got was only 6686 I. H. P., showing that they were deficient to the extent of nearly 10 per cent. The total coal burned on the eight hours' trial was 100,890 lb., equal to 1.88 lb. per I. H. P. hour. An equal proportion of Babcock and Wilcox boilers, working at the same power, and burning in the eight hours 100,498 lb. of coal, the air pressure in the stokehold being 0.8, gave 7510 I. H. P., which was 300 more than was anticipated, while their coal consumption was only 1.67 lb. per I. H. P. per hour. In other words, for the same coal consumption, the water-tube boilers gave over 12 per cent. more power, and the ratio of consumption to power was 0.21 lb. less per unit of power per hour = 11 per cent. less than with tank boilers."

Forced Draught. — For full efficiency under forced draught a boiler should have sufficient furnace volume for complete combustion at the maximum rate of coal comsumption to be attained; an area of heating surface adequate, when fully effective, to lower the temperature of the maximum weight of combustion gases thus produced to that of the normal temperature of the stack; and a system of baffling — either by tube walls or sheet-metal partitions — so designed as to make the whole area of the heating surface effective and to give the greatest possible travel to the gases in their passage from furnace to uptake, while not increasing unduly the draught resistance of the boiler.

These are the ideal conditions for fully efficient forcing — conditions which the limitations of marine practice make difficult of fulfillment. It is true that large powers have been developed at low air pressures by the high forcing of boilers whose absence of baffling gave them slight draught resistance; but the expenditure of fuel per boiler horse power is in such cases correspondingly large, since the gases take the shortest road to the uptake, the entire heating surface is not effective, and the stack temperature is abnormally high.

In the *Cincinnati* tests the Babcock and Wilcox boilers reached a maximum consumption of 59.23 pounds dry coal per hour per square foot grate surface, the temperature of the escaping gases from the boiler being given as "less than 900° F.," the equivalent evaporation — from and at 212° — as 9.63 pounds, and the boiler efficiency, on the dry

coal basis, as 63.4 per cent. In the *Nebraska* tests, at a consumption of 37.88 pounds dry coal per hour per square foot grate surface, the equivalent evaporation from and at 212° was 10.8 pounds per pound of dry coal, which amount was 98.4 per cent. of the maximum evaporation, the latter having been obtained at a coal consumption of 31.5 pounds.

Lieutenant Commander Bryan states, as to naval practice: "It is not believed that more than 40 pounds coal per square foot grate surface per hour can be maintained for ninety-six hours, nor more than 45 to 50 pounds for twelve hours under service conditions" — an opinion which is fully sustained by knowledge of the added and severe work of the fire room complement, especially with the closed stokehold system, and of the rapid clogging of the grate bars under any system. In the *Nebraska* tests the Babcock and Wilcox boiler seems to have come fairly close to the 40-pound limit, and with fair evaporative efficiency.

The *Nebraska's* boiler had two furnaces, each with three fire doors, and both opening into the same tube space above. A fact which was brought out on these tests was that the closed ash-pit system of forced draught was unsuitable for high rates of combustion in a boiler of this type. "It was found, with even the lowest draught pressure used, that it was not safe to work the fires when under ash-pit draught without closing off the draught from both furnaces," since the firemen were endangered by a cloud of sparks from the fires. As a result the draught was entirely closed off on Test I for 23.4 per cent., on Test II for 24.6 per cent., and on Test III for 28.4 per cent. of the whole time of the test.

Make-up Feed. — A minor objection which has been urged against boilers having joints in the water space, similar to the hand-hole plates at the tube ends of the Babcock and Wilcox boiler, is the additional amount of "make-up feed" required, owing to the loss from leakage at such joints. The total loss covers, of course, all leakage at the engine and auxiliaries, the escape at the safety valves, etc.

An old and apparently low estimate for the loss with cylindrical boilers is 1 ton of make-up feed per 1,000 I. H. P. of main engines for each twenty-four hours. Commander White[1] found for the United States cruiser *Minneapolis* (cylindrical boilers) a feed loss of 6.58 tons per 1,000 I. H. P.; when the engines were running at 8 per cent. of their maximum power, Lieutenant Dinger[2] estimates the make-up feed

[1] Journal of the American Society of Naval Engineers, X, No. 1.

[2] *Ibid.*, XV, No. 1.

of the United States steamship *Marietta* (Babcock and Wilcox boilers) as 4 to 5 tons per 1,000 I. H. P. per day. The British Committee on Naval Boilers, in the report previously cited, give the feed loss of the *Hermes* (Babcock and Wilcox boilers) as 3.8 tons per 1,000 H. P. per day, which the committee state is "moderate."

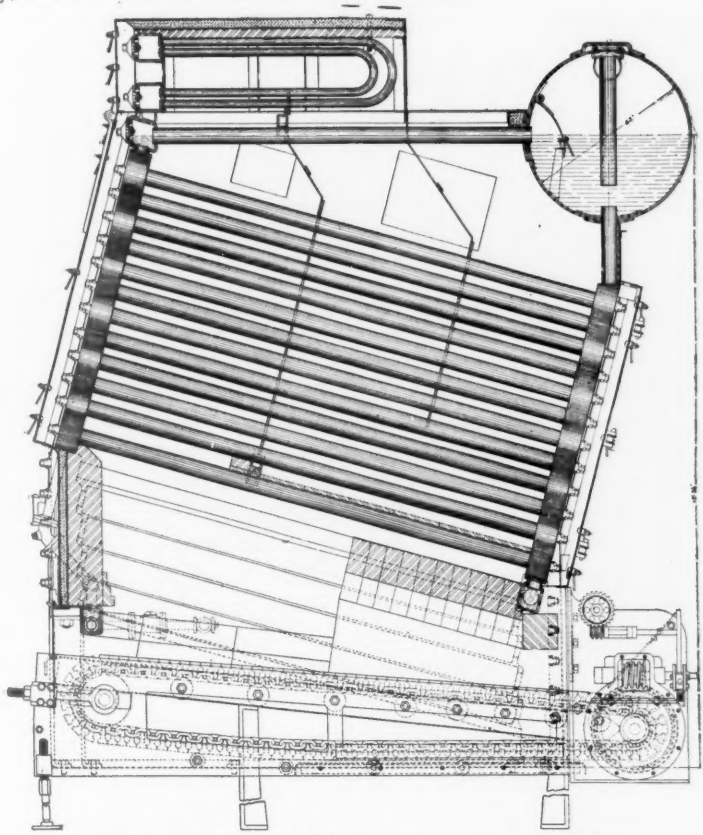


FIG. 10.— BABCOCK AND WILCOX BOILER WITH SUPERHEATER

Against the increased loss of feed from the number of hand-hole plates in the Babcock and Wilcox boiler there must be balanced the advantage which these plates give of ready access to the water side of the heating surface. This advantage is one factor in maintaining the efficiency of this boiler in continuous service.

Firing. — A further objection frequently advanced against the water-

tube boiler is that a higher degree of skill in firing is required to secure good results than with the cylindrical boiler. This is quite true, owing to the smaller amount of contained water and to the larger area of grate surface in a single furnace. There should be a uniform thickness of fire, since an inrush of cold air will occur at thin spots. As a general rule, firing thinly, evenly, and often is essential for efficiency.

In the *Nebraska* tests the total grate surface was 111.72 square feet; number of furnaces, two; doors per furnace, three; grate surface per door, 18.62 square feet. In burning 37.88 pounds dry coal per hour per square foot grate surface, the average amount of coal fed at each door at each coaling was 101.8 pounds; the average time between consecutive coalings or levelings at the same door was eight minutes twenty-one seconds; and the average coal fired at each coaling (three doors) was 305.4 pounds.

Feed Appliances. — There are no special feed appliances in the Babcock and Wilcox boiler. The system, in valves, piping, and pumps, is practically the same as with the cylindrical boiler.

Cleaning and Repairs. — The tubes are staggered vertically only and not horizontally. Hence they lie in horizontal rows, leaving "lanes" between the rows for the insertion of the steam lance in blowing soot from the tubes. This method removes the bulk of the soot, which is carried up the smoke pipe by the draught. When the boiler is out of use the cleaning or "dusting" doors give access to each "pass."

The straight tubes and expanded joints of this boiler make repairs to the pressure parts simple. Of those parts the headers are the only ones of special form. These in manufacture are subjected to a hydrostatic pressure of 600 pounds to the inch in order to detect leaks, defects in welding, etc.

Superheated Steam. — The Babcock and Wilcox Company has led in the reintroduction of the superheater in American vessels. Figure 10 shows this superheater as fitted in the boilers of the *James C. Wallace*, a lake steamer having one quadruple expansion engine of 2,000 I. H. P.

The superheater is located at the rear of the boiler above the circulating tubes, and consists of solid-drawn steel tubes bent in U-form, each connected by expanded joints to an upper and a lower cross box, or steam collector, of wrought steel. Steam is led from the steam and water drum to the upper box by an outside pipe, and, since there is one partition in each box, it flows three times through the tubes from one box to the other before leaving the

superheater for the engine by another outside pipe. Valves are fitted in the piping, so that the steam from the boiler may be sent either through the superheater or directly to the main steam line.

The principal data relating to the superheaters of the *Wallace* are:

Diameter of superheating tubes, inches	2
Thickness of superheating tubes, inches	10 B. W. G
Number of boilers	2
Grate surface, each boiler, square feet	74
Heating surface, each boiler, square feet	2,900
Superheating surface, each boiler, square feet	414
Ratio of grate surface to heating surface	1 to 30.19
Ratio of grate surface to heating surface, including superheating surface	1 to 44.78

As shown, a damper depends from the middle of the base of the superheater. In this position its lower edge rests upon the top of the rear upright baffle, and the gases are thus forced to flow around the superheater tubes on their way to the passage between the two upright baffles. In comparative tests[1] made by a board of officers of the United States Navy trials with superheated steam were made with this damper in position, and later with saturated steam, the damper being removed and the superheater blocked off by a fire-brick baffle laid on the circulating tubes.

The principal data of the tests are given below, Test I having been with superheated and Test IV with saturated steam. In these tests the conditions were closely similar, except as to the state of the steam and the points of cut-off, the latter differing in order to develop the same power with both superheated and saturated steam.

[1] Journal of American Society of Naval Engineers, XVII, No. 3.

	Test No.	
	I.	IV.
Duration, hours	8.0	6.0
Steam pressure, gauge, pounds:		
At boilers	237.6	238.7
At engine	233.7	237.8
Steam temperature, degrees F.:		
Leaving superheater	487.0	. .
At engine	482.2	. .
Superheat at engine, degrees F.	81.7	0.0
Vacuum, inches	24.5	24.6
Revolutions per minute	79.0	77.0
I. H. P., main engines only	1,559.2	1,530.5
Kind of draught	Natural	Natural
Draught (inches of water), base of smoke pipe	.22	.22
Temperature, base of smoke pipe, degrees F.	485.3	553.5
Pounds of coal:		
Per hour, as fired	2,362.5	2,700.0
Per I. H. P.-hour, dry	1.464	1.713
Per hour, per square foot grate surface, moist	15.96	18.24
Moisture, per cent.	3.38	2.88
Ashes in coal, per cent.	19.87	14.4

The power developed by the auxiliaries in use was not determined. The water evaporated was not weighed, as facilities were lacking. Tests as to quality, made during the trials with saturated steam, showed that the latter was practically dry.

A comparison based on dry coal per I. H. P.-hour shows a net saving in fuel by the use of superheated steam of 14.5 per cent. In considering this result, it should be noted that it represents the aggregate saving throughout the entire plant and not only that due to the main engines. The proportionate saving for the main engine can be determined only from data as to its steam consumption, which data are, as stated, lacking in this case.

BLACK SAND OF THE PACIFIC COAST

By ROBERT H. RICHARDS

(Read December 14, 1905)

Dr. Day, Chief of the Department of Mineral Resources of the United States, when looking for lines along which the United States Geological Survey could serve the people, was impressed with the possibilities of black sand, and in 1897 and 1898 visited many beaches on sea and rivers, panning the sands for gold and platinum. He concluded that the troublesome black sand was worth investigation. Congress early in 1905 appropriated $25,000 for this work.

The Lewis and Clark Exposition of 1905 gave the opportunity for the concentrating pavilion and the concentrating machines, together with a supply of power and water. The Board of Trade of Portland furnished sea sand and river sand in carload lots. The hydraulic plants and dredges furnished clean-up sand and tailings for the tests.

Dr. Day brought together an efficient corps of workers for the Pavilion and the Mines Building. The miners washing gold in any part of the United States were invited to send 4-pound samples by mail for tests. These were examined for interesting minerals by Dr. C. H. Warren, assisted by Mr. Loughlin, and were assayed for gold, platinum, iridium, and iridosmine by Mr. C. E. Locke, assisted by Messrs. Barnaby, Brown, Glidden, Hayden, Reed, Johnston, and Whiting. When any samples showed interesting values the owners were asked for an additional quantity. In this way lots of from 100 pounds to 15 tons were received for investigation and treatment at the Pavilion; altogether 1,000 of the little samples and 250, more or less, of the larger quantities were examined.

These sands may be classified into sea beach, river beach, hydraulic tailings and clean-ups, dredge tailings and clean-ups, and finally ore from veins in place.

The interesting minerals proved to be magnetite, chromite, ilmenite, garnet, monazite, and zircon.

The usual fire assay treating 30 grams, while very satisfactory for richer ores, failed when samples carrying one cent, five cents, or twenty-five cents gold per ton were to be accurately valued. A two-gallon bottle revolving endwise with a little sodium amalgam — 50 grams — could treat 1,000 or 2,000 grams at a charge, and proved extremely valuable. Screens proved very useful, and the sizes adopted had 8 mm., 2 mm., and ½ mm. holes. Hand jigs proved valuable on the size larger than 8 mm. and the size between 8 mm. and 2 mm. They separated the gold and heavy minerals very effectively from the sands. The classifier is an instrument which acts by means of a current of water, which rises in a vertical tube and allows grains that can settle against the current to go down and out, while those that cannot do so rise and go over. A number of such tubes, with rising currents graded from faster to slower, can make a series of products decreasing in settling power. A classifier with twenty-four tubes, treating coarse gold in hydraulic clean-up sand, caught all the gold in the first three tubes — a very good result. But the same classifier treating sea-beach sand with fine flakes of gold showed some of that metal even in the twenty-fourth tube, and was entirely unsatisfactory. This sand proved to have been already classified by the waves.

The Wilfley table showed wonderful power, not only for saving coarse gold and platinum in clean-up sand, but for the fine leaf gold of the sea sand; and it also saved with ease the heavy minerals in the sand. It acts by a jerking motion which throws forward the heavy minerals into a sort of procession, while the lighter waste is thrown out and away from them on one side.

The Wetherill magnet is a valuable machine, and lifts out magnetic grains from a procession of sands passing under it on a belt and deposits them in a box by themselves, while the non-magnetic grains are dumped into another box by the belt. It usually has six magnetic poles, beginning with the weakest and ending with the strongest. In the Portland work the electric currents for these poles were:

0.2 amperes to lift out magnetite;
0.8 amperes to lift out ilmenite and chromite;
1.75 amperes to lift out garnet;
1.90 amperes to lift out hypersthene;
3.50 amperes to lift out monazite and to leave zircon behind.

Magnetite is the richest of the iron ores and is worth one-fourth of

a cent a pound. Chromite is valuable for colors, yellows and greens, and for chrome steel, which is worth one and one-half cents per pound. Ilmenite is beginning to attract electricians and may have a value later. Garnet for polishing powder may sell for one and one-half cents a pound, according to quality. Hypersthene has no value. Monazite (thorium phosphate) is used in making Welsbach light mantles and is valued at ten cents a pound. Zircon (zirconium silicate) is used in the same way and has the same value.

The electric steel furnace is as novel as any instrument employed in this investigation by the United States Geological Survey, and is more striking and spectacular. The furnace used at Portland is of experimental size. It consists of a hollow cylinder standing on end, 12 inches in diameter and 36 inches high inside. It is lined with fire brick except at the bottom, which has carbon bricks for conducting electricity, and under it is a heavy iron plate for distributing the electricity to the carbon bricks. The current used is 1,000 amperes at 56 volts. There was boundless enthusiasm among the Portland people who had gathered to see it when, in an hour and a half after this furnace was started cold on concentrates from the sea beach, 200 pounds of white hot steel was tapped from it. This furnace has proved immune from the harm of titanium, the bugbear which has wrecked so many efforts to use iron ores containing that metal. It is still in the experimental stage as to the means of controlling the contents of the steel in silicon, carbon, manganese, sulphur, and phosphorus. This control, as well as the means for obtaining sound ingots free from bubbles, will have to come by experiment. At the time of writing it does not look as if any of these would give serious trouble.

The cost of the furnace work on the little experimental furnace is estimated as follows:

4 men at $3 a day	$12.00
Electricity at 75 H. P., $50 per H. P. per year	12.00
1 anode 4 inches x 4 inches x 4 feet	6.00
Repairs	5.00
2,400 pounds steel cost	$35.00
1 ton (2,000 pounds) steel cost	29.00

Milling and furnace work on a basis of 100 tons per twenty-four hours:

Water concentration, 100 tons { lifting, 9c. per ton; washing, 6c. per ton } 15c.,	$15.00
Drying 49.8 tons at 20c.	10.00
Magnetic concentration, 49.8 tons at $1	49.80
Smelting into 16.1 tons steel at $29	467.00
	$541.80

Yield of 100 tons, best lot Fort Stevens[1]:

Magnetite, 32.2 tons, or steel, 16.1 tons, at 4c. a pound .	$1,288.00
Ilmenite, 8.6 tons at a pound	
Garnet, 8.7 tons at 1½c. a pound	261.00
Monazite, 80 pounds at 10c. a pound	8.00
Zircon, 500 pounds at 10c. a pound	50.00
Gold and platinum, at 53c. a ton	53.00
	$1,660.00

NOTE. — Since the work is at present in a purely experimental stage the above figures are the best that the writer is able to give at this time. They will undoubtedly have to be modified, perhaps in some important directions; for example, the price of steel at four cents a pound may prove to be too high for the quality of steel that this furnace is able to produce.

[1] The sand selected for the following computation of yield and cost was the richest sand that came from the sea beach during the season. It came in a 15-ton lot from near Fort Stevens, near the mouth of the Columbia River. There is said to be a large quantity of it at that point.

The wisdom of selecting the richest sample may be questioned, as one would naturally like to hear from an average sample. The work has not progressed to a point where this is obtainable, however.

A NEW RAPID PRESUMPTIVE TEST FOR BACILLUS COLI IN WATER

By G. R. SPALDING

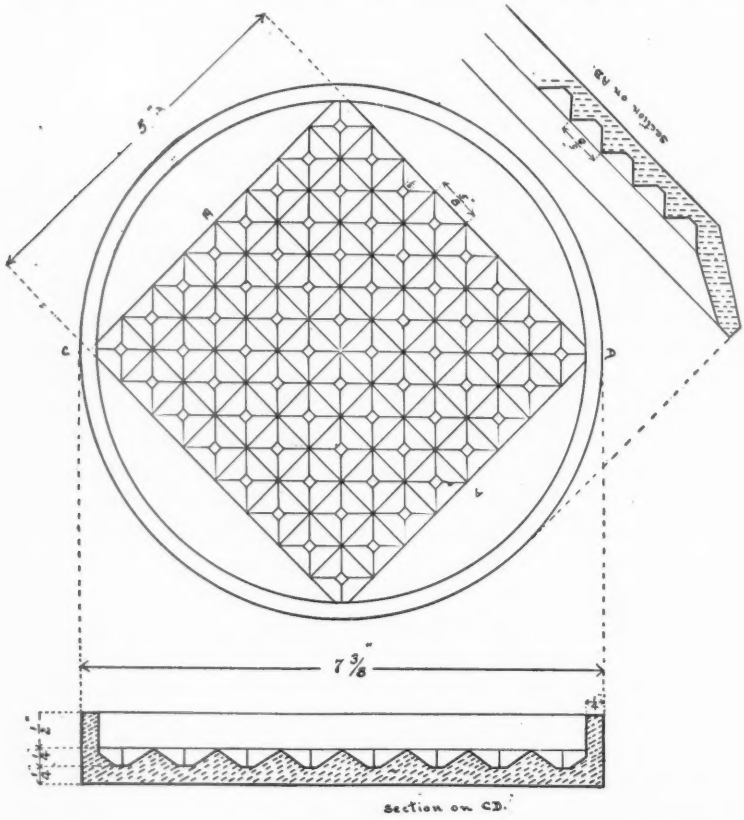
Superintendent of the New Milford plant of the Hackensack Water Company

In the control of municipal filter plants it is important to determine, in the shortest possible time, the extent to which *Bacillus coli* and other gas-producing organisms have been removed. For this purpose the "Indented Plate," represented in the accompanying figure, has been devised.

B. coli and other sewage bacteria grow most rapidly in liquid media at temperatures slightly under 40° C. On the other hand, solid media are much better adapted to exact quantitative work than the ordinary fermentation tube. In the process here described the attempt has been made to combine the advantages of both solid and liquid media so as to obtain exact quantitative results in the shortest possible time. This has been accomplished by the use of a large glass plate with sixty-four small indentations, the design of which is shown in the figure. Among the cavities or indentations from 1 to 5 c.c. of the water, diluted and mixed with litmus sugar broth, is carefully distributed. As short a period of incubation as eight hours amply suffices to differentiate those cavities in which acid-forming organisms are present. The process is, in fact, the old dilution method of Miquel, so modified as to be of use on a practical scale.

In the control of the mechanical filter plant at New Milford the author has used the indented plate in testing for acid formation, gas formation, and gas ratio in the unfiltered and filtered waters in the following manner: a concentrated lactose broth, five times as strong as ordinary broth, is prepared and tubed. One c.c. of this broth and 1 c.c. of the river water are added to 9 c.c. of sterile water, 1 c.c. of litmus added, and the mixture poured into the plate. Violent, lateral agitation is necessary to distribute the solution evenly in the cavities. With the filtered effluent, 5 c.c. of the sample are diluted with 5 c.c. of sterile water, and 1 c.c. each of broth and litmus added. Plates show formation of acid in eight hours, and, if made late in the afternoon,

are ready to be reinoculated into fermentation tubes the next morning. Any cavities showing acid formation are thus reinoculated, so that the tubes shall be ready for examination for gas on the following morning. The number of cavities showing acid formation has proved to be of considerable value in this work as an indication of the degree of puri-



fication, but only a small percentage of such acid cavities subsequently give typical gas formation. With the use of a certain amount of personal equation in adapting the method to suit the requirements of the work in hand, it is the opinion of the author that the indented plate will be found of considerable value in following the bacterial changes in water filtration and in other processes.

THE DISTRIBUTION OF LOADS ON STRINGERS OF HIGHWAY BRIDGES CARRYING ELECTRIC CARS[1]

By F. P. McKIBBEN

In many highway bridges which carry a street railway track the rails are laid directly upon a layer of planking, which in turn rests upon the track stringers, as shown in Figure 1. This is a common method of supporting the rails on old bridges originally designed to carry only ordinary highway traffic, over which street railway tracks were subsequently laid. If the floor planking is laid transversely, it will act as a series of transverse beams and will thereby transfer part of the rail

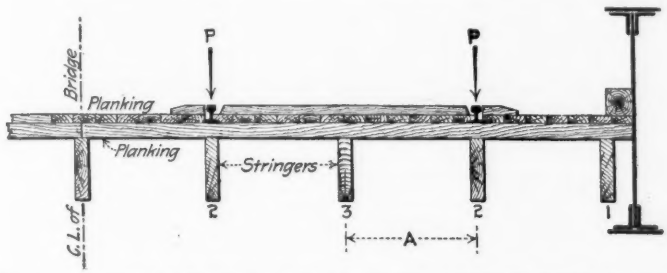


Fig. 1.—Transverse Section of Floor of Old Highway Bridge Carrying Electric Railway Tracks.

load to stringers not immediately under the rail, and correspondingly reduce the load on the rail stringers. The distribution of the wheel loads over the floor stringers of such a bridge is the subject of the following study:

Given: P, the load on each rail, assumed at the centre of the panel.

L, the panel length.

A, the distance, centre to centre, of stringers.

I, moment of inertia of the cross section of the planking over which the loads P are distributed.

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[1] Reprinted from Engineering News, April 12, 1906, 55, No. 15.

I_1, moment of inertia of each of the stringers.

E, modulus of elasticity of wood.

Required: F_1, F_2, F_3, the amounts of load borne by stringers 1, 2, 3, respectively.

We have the three unknown quantities, F_1, F_2, F_3, and must, therefore, have three independent equations. These are deduced as follows:

$$2F_1 + 2F_2 + F_3 = 2P \quad \ldots\ldots \quad (1).$$

A second equation may be obtained by equating the difference between the deflections of the points 1 and 2 of the planking and the difference between the deflections of the same points of stringers 1 and 2. The third equation may be obtained by equating the difference between the deflections of the points 2 and 3 of the planking and the difference between the deflections of the same points of stringers 2 and 3.

The effect of the upper layers of planking will be neglected. The effect of the lower layer will be assumed to be as shown in Figure 2. Taking the lower layer of planking to be a beam with free ends at stringer 1, it will be sufficient, because of symmetry about 3, to consider only the section 3-1, represented by a cantilever beam fixed at 3 and loaded at 2 (by P and F_2) and at 1 (by F_1). Then the following expressions hold:

Deflection of point 2, with reference to point 3:

$$\text{Downward, due to load } (P - F_2) \text{ at point 2, } = \frac{(P - F_2)\,A^3}{3\,E\,I}.$$

$$\text{Upward, due to load } F_1 \text{ at point 1, } = \frac{5\,F_1\,A^3}{6\,E\,I}.$$

$$\text{Resultant, downward, } d_{23} = \frac{A^3}{6\,E\,I}\,(2\,P - 2\,F_2 - 5\,F_1).$$

Deflection of point 1, with reference to point 3:

$$\text{Downward, due to load } (P - F_2) \text{ at point 2, } = \frac{5\,A^3\,(P - F_2)}{6\,E\,I}.$$

$$\text{Upward, due to load } F_1 \text{ at point 1, } = \frac{8\,F_1\,A^3}{3\,E\,I}.$$

$$\text{Resultant, downward, } -d_{13} = \frac{A^3}{6\,E\,I}\,(5\,P - 5\,F_2 - 16\,F_1).$$

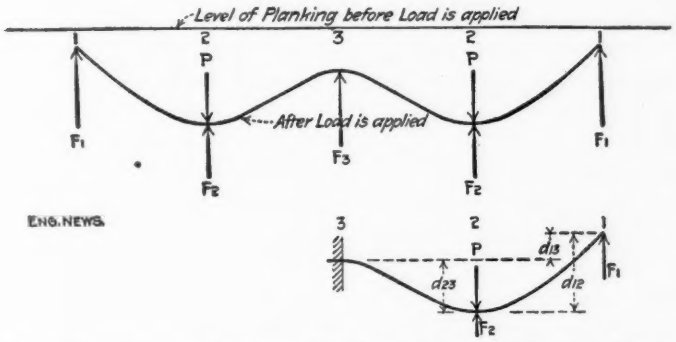

FIG. 2.—DIAGRAM OF STRINGER LOAD DISTRIBUTION ON HIGHWAY BRIDGE FLOOR CARRYING ELECTRIC RAILWAY TRACK

The difference in deflection of the planking at points 1 and 2 is (see Figure 2):

$$d_{12} = d_{23} + d_{13} = \frac{A^3}{6\,E\,I}(3\,F_2 - 3\,P + 11\,F_1).$$

Equating this with the difference in deflection of stringers 1 and 2 at the centre of the panel, we have

$$\frac{L^3}{8\,I_1}(F_2 - F_1) = \frac{A^3}{I}(3\,F_2 - 3\,P + 11\,F_1) \quad \ldots\ldots (2),$$

the value of the modulus of elasticity E being the same for stringer and planking.

Similarly, the expression above given for d_{23} (the difference of deflection between points 2 and 3) may be equated to the difference of deflection in the corresponding stringers. This gives the third equation required:

$$\frac{L^3}{8\,I_1}(F_2 - F_3) = \frac{A^3}{I}(2\,P - 2\,F_2 - 5\,F_1) \quad \ldots\ldots (3).$$

The solution of equations (1), (2), and (3) gives the following values for F_1, F_2, and F_3:

$$F_1 = \frac{2\,P\,L^3\,I\,(20\,A^3\,I_1 + L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

$$F_2 = P - \frac{P\,L^3\,I\,(128\,A^3\,I_1 + 3\,L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

$$F_3 = \frac{2\,P\,L^3\,I\,(88\,A^3\,I_1 + L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

The accompanying table shows some values of the loads F_1, F_2, and F_3 as given by the above formulas. An examination of the table will show that an axle load of 15,000 pounds has been assumed on a panel length of 13 feet, with stringers spaced 30 inches apart. The thickness of the planking has been taken as 3 inches, and the axle load has been assumed to be distributed by the rails over 20 inches of the planking.

The table shows, for example, that for stringers 4 x 14 inches 7.2 per cent. of the axle load is carried by each outside stringer, 30 per cent. by each of the stringers under the rails, and 25.6 per cent. by the stringer under the centre of the track.

The above computations have been made to show how the loads are distributed under the most favorable circumstances. Oftentimes the planking is so decayed that it transfers little load to the adjacent stringers, and the stringers directly under the rails carry practically the entire load.

If the loads P are placed at the *end of the panel* instead of at the centre, the planking has no effect in distributing the loads over the adjacent stringers, and the stringers directly under the rails carry the entire track load.

In designing a new structure of this kind, the stringers under the rails should be made of sufficient size to carry the track loads without any assistance from the adjacent stringers.

TABLE SHOWING DISTRIBUTION OF LOADS ON STRINGERS OF HIGHWAY BRIDGES CARRYING ELECTRIC CARS

Thickness of planking.	Distribution of load on planking.	Size of stringers.	Spacing of stringers. A.	Span of stringers. L.	Total load per axle $2P$ (pounds).	Load Carried by Each Stringer (Pounds).			Per Cent. of Total Axle Load Carried by Each Stringer.		
						F_1.	F_2.	F_3.	Outside stringer.	Stringer under each rail.	Centre stringer.
3″	20″	3 x 14″	30″	156″	15,000	1,195	4,316	3,978	8.0	28.8	26.4
3″	20″	4 x 14″	30″	156″	15,000	1,088	4,494	3,836	7.2	30.0	25.6
3″	20″	6 x 14″	30″	156″	15,000	941	4,788	3,542	6.3	31.9	23.6

TESTS ON A VACUUM SWEEPER

By EDWARD F. MILLER

The following tests were conducted by the fourth-year students as a part of the regular assigned work of the Engineering Laboratories of the Massachusetts Institute of Technology, and were made under the direction of Mr. A. H. Smith of the instructing staff of the laboratory.

The apparatus was presented by the Sanitary Devices Company. It consisted of a double-acting vacuum pump 8 inches diameter by 12 inches stroke, having a piston rod 1¼ inches in diameter; two dust removing tanks (one wet and one dry); about 100 feet of rubber pipe 1 inch inside diameter; an inrush sweeper made by the Sanitary Devices Company; and a D. T. Kenney sweeper. These sweepers are designated in the tests which follow as Inrush and Vacuum.

Indicators were attached to the air pump, and the power used in the pump cylinder was calculated from cards taken during each test.

All of the tests were conducted in practically the same way. In some of the first tests dirt, meal, flour, etc., were used on the carpet, but later on a fine sand resembling street dust was used. This sand was found during the excavation of the East Boston Tunnel. It was used in all of the tests quoted in this article.

A Kazak rug 3 feet 6 inches by 9 feet was charged with a certain amount of this sand by sprinkling the sand on the rug and then thoroughly treading it in. The rug was then weighed on a special scale known as a silk scale. This scale was read to the nearest one-fourth ounce. The rug was then swept with one sweeper for a period of ten minutes, weighings of the rug being made at the end of each two-minute period.

The rug was again charged with sand till it weighed about the same as before, and then swept in the same way with the other sweeper.

From day to day the order in which the sweepers were used was changed. It will be noticed that the ten-minute sweeping was not

sufficient to remove all of the sand added, as the carpet gradually grew heavier.

As might be expected, some were more expert in using the sweepers than others. This was particularly noticeable with the Inrush sweeper, which on account of its broader base was more difficult to keep to an even bearing on the carpet than the Vacuum sweeper with its very

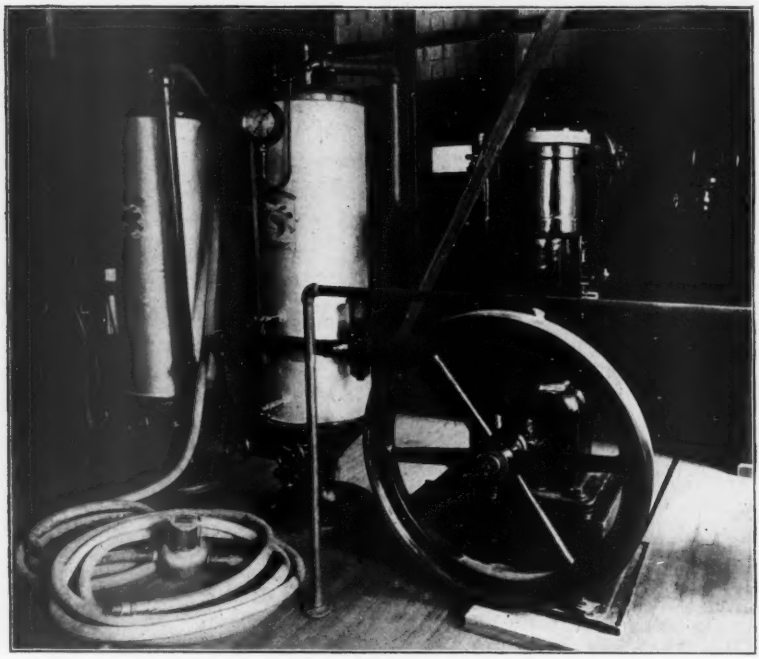

FIG. 1. — VACUUM PUMP AND DUST TANKS

narrow base. The Vacuum sweeper had a slot $14\frac{3}{4}$ inches long and $\frac{1}{16}$ inch wide.

The opening for inrush of air in the Inrush sweeper was .05 inch wide and $11\frac{5}{8}$ inches long. The opening beyond was $11\frac{5}{8}$ inches by $\frac{5}{16}$ inch. The bridge between the two openings was about .04 inch above the plane of the face of the sweeper. The foot of the sweeper was $1\frac{3}{4}$ inches wide.

FIG. 2. — VACUUM AND INRUSH SWEEPERS

SUMMARY

Series.	DIRT REMOVED PER MINUTE PER CUBIC FOOT OF FREE AIR.		DIRT REMOVED PER MINUTE PER HORSE POWER OF AIR CYLINDER.		AVERAGE VACUUM IN INCHES.		HORSE POWER.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
I_0	.00185	.00254	.0438	.0631	12.73	12.11	2.018	2.008
II_0	.00154	.00182	.0292	.0364	14.00	13.49	2.675	2.658
III_0	.00061	.00132	.0142	.0314	12.68	12.30	2.068	2.073

An investigation carried on as thesis work by Messrs. Patterson and Phelps showed that the most economical vacuum for each sweeper was between 15 inches and 16 inches. In all of their work the sweeper was held in a carriage so that it bore perfectly on the carpet and gave the best condition possible for efficient sweeping. They found that the force needed to push the two sweepers over a carpet was practically the same for one sweeper as for the other. Their experiments were made on a Wilton carpet and the Kazak rug.

TESTS ON VACUUM CLEANERS

	No.	Revolutions per Minute.		Vacuum.	
		Vacuum.	Inrush.	Vacuum.	Inrush.
		1	2	3	4
I_0. Tests 7–28, vacuum = 12.0″–12.5″	7	108	113	12.2	12.2
	8	117	115	12.2	12.3
	9	121	120	12.5	12.5
	10	124	116	12.4	11.8
	13	120	121	13.7	12.7
	14	124	125	13.2	11.7
	16	120	121	13.0	12.1
	17	124	121	12.8	12.4
	19	122	120	13.1	12.1
	20	121	124	12.7	12.2
	21	120	120	13.1	11.8
	22	120	120	12.5	11.8
	23	120	121	13.1	12.5
	24	120	120	12.3	11.8
	25	120	120	13.0	12.6
	26	121	121	13.2	12.8
	28	122	122	11.4	10.6
	Average	120.3	120.0	12.73	12.11

	No.	Revolutions per Minute.		Vacuum.	
		Vacuum.	Inrush.	Vacuum.	Inrush.
		1	2	3	4
II_0. Tests 29–44, vacuum = 13.5″–14.0″	29	147	146	13.1	12.4
	30	143	143	13.0	12.9
	31	144	148	13.6	12.6
	32	147	147	13.9	13.2
	33	145	146	14.0	13.5
	34	140	140	14.0	13.5
	35	144	144	14.5	14.0
	36	146	146	14.5	13.7
	37	141	140	14.2	13.9
	38	147	146	14.4	13.6
	39	145	144	14.8	14.0
	40	144	143	13.9	13.5
	41	145	145	14.4	13.8
	42	145	145	13.9	13.7
	43	147	147	14.1	13.5
	44			13.9	14.2
	Average	144.7	144.7	14.00	13.49

TESTS ON VACUUM CLEANERS

VACUUM.

No.	Weight of carpet plus the dirt. Pounds.	Dirt removed in first two minutes. Pounds.	Dirt removed in second two minutes. Pounds.	Dirt removed in third two minutes. Pounds.	Dirt removed in fourth two minutes. Pounds.	Dirt removed in fifth two minutes. Pounds.
	5	6	7	8	9	10
7	28.42	.77	.30	.17	.19	.11
8	28.31	.41	.32	.19	.14	.10
9	29.78	.40	.11	.11	.08	.06
10	30.62	.41	.12	.06	.09	.09
13	29.97	.33	. .	. .	. .	. .
14	30.86	.48	.41	.53	.23	.22
16	30.44	.56	.23	.12	.12	.11
17	30.55	.36	. .	. .	. .	. .
19	29.22	.22	.11	.07	.05	.07
20	30.22	.41	. .	. .	. .	. .
21	30.28	.28	.16	.12	.09	.08
22	30.55	.30	.11	.11	.06	.03
23	31.08	.44	.17	.13	.08	.07
24	30.69	.27	.14	.20	.06	.05
25	31.48	.34	. .	. .	. .	. .
26	31.69	.31	.17	.11	.09	.09
28	32.52	.39	.22	.10	.11	.07
29	30.25	.42	.06	.06	.06	.06
30	30.40	.24	.11	.15	.13	.06
31	31.08	.34	.09	.09	.08	.06
32	31.50	.31	. .	. .	. .	. .
33	31.76	.31	. .	. .	. .	. .
34	31.50	.22	. .	. .	. .	. .
35	31.91	.27	.08	.05	.06	.06
36	33.25	.22	.13	.09	.09	.09
37	33.94	.38	.18	.16	.09	.10
38	34.44	.33	.25	.11	.14	.07
39	34.59	.41	.16	.12	.09	.09
40	35.05	.36	.17	.14	.09	.08
41	35.25	.41	.22	.14	.17	.12
42	35.38	.25	.13	.09	.08	.08
43	36.12	.38	.16	.14	.12	.03

INRUSH.

No.	Weight of carpet plus the dirt. Pounds.	Dirt removed in first two minutes. Pounds.	Dirt removed in second two minutes. Pounds.	Dirt removed in third two minutes. Pounds.	Dirt removed in fourth two minutes. Pounds.	Dirt removed in fifth two minutes. Pounds.
	11	12	13	14	15	16
7	28.34	.41	.47	.31	.34	.28
8	28.39	.47	.17	.20	.14	.19
9	29.72	.64	.27	.20	.14	.11
10	30.66	.25	.11	.19	.08	.25
13	29.94	.37	.33	.19	.17	.09
14	30.88	.53	.19	.20	.09	.17	
16	30.20	.76	.36	.29	.28	.25
17	30.59	.50	.44	.34	.22	.28
19	29.22	.44	.23	.13	.16	.10
20	30.22	.39	. .	. .	. .	. .
21	30.28	.34	.25	.17	.17	.20
22	30.58	.36	.14	.17	.10	.15
23	31.11	.47	.20	.17	.20	.22
24	30.69	.22	.14	.11	.09	.08
25	31.48	.41	. .	. .	. .	. .
26	31.72	.38	.26	.16	.17	.14
28	32.55	.36	.13	.20	.09	.13
29	30.25	.44	.30	.19	.17	.09
30	30.40	.20	.13	.13	.11	.10
31	31.08	.41	.30	.08	.16	.19
32	31.60	.22	. .	. .	. .	. .
33	31.76	.24	. .	. .	. .	. .
34	31.50	.36	.13	.16	.15	.11
35	31.85	.36	.17	.11	.09	.08
36	33.25	.51	.25	.19	.16	.11
37	33.97	.22	.25	.16	.12	.09
38	34.42	.42	.27	.29	.15	.14
39	34.61	.50	.20	.12	.19	.12
40	35.05	.42	.25	.16	.16	.17
41	35.24	.45	.22	.17	.13	.12
42	35.38	.33	.17	.16	.09	.13
43	36.13	.20	.11	.20	.06	.09

No.	Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air per Minute.		Horse Power of Pump.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
	17	18	19	20	21	22	23	24	25	26
7	1.53	1.81	.086	.097	84.7	85.3	. .	. .	1.79	1.88
8	1.17	1.17	.060	.060	82.8	86.2	. .	. .	1.95	1.95
9	0.76	1.36	.036	.067	84.7	83.3	. .	. .	2.13	2.03
10	0.78	0.88	.038	.047	83.6	80.2	. .	. .	2.07	1.87
13	0.69	1.15	.031	.053	82.7	83.6	. .	. .	2.20	2.17
14	1.18	1.89	.053	.091	84.3	85.9	. .	. .	2.07	2.21
16	1.14	1.97	.057	.102	82.5	82.7	. .	. .	2.00	1.93
17	0.95	1.78	.046	.089	84.8	83.6	. .	. .	2.06	2.01
19	0.52	1.06	.025	.055	83.8	82.2	. .	. .	2.12	1.94
20	0.84	1.41	.042	.066	83.6	86.2	. .	. .	2.01	2.13
21	0.73	1.14	.036	.057	80.9	82.8	. .	. .	2.06	2.01
22	0.61	0.92	.030	.047	81.2	84.4	. .	. .	2.01	1.98
23	0.89	1.27	.042	.058	83.8	85.5	. .	. .	2.14	2.18
24	0.72	0.64	.035	.032	82.2	83.3	. .	. .	2.04	2.02
25	0.85	1.10	.041	.052	81.7	82.8	. .	. .	2.07	2.10
26	0.78	1.11	.037	.052	83.4	83.2	. .	. .	2.12	2.13
28	0.89	0.91	.050	.052	82.6	83.9	. .	. .	2.78	1.76
. .	150.3	2.157	.745	1.077	. .	. .	. .	. .	. .	. .
Av.	0.884	1.269	.0438	.0632	83.14	83.83	.00106	.00151	2.018	2.008
					Free air per minute,		.00185	.00254		

No.	Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air per Minute.		Horse Power of Pump.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
	17	18	19	20	21	22	23	24	25	26
29	0.67	1.19	.026	.047	54.8	57.7	. .	. .	2.55	2.50
30	0.69	0.67	.028	.029	54.1	55.0	. .	. .	2.48	2.54
31	0.66	1.14	.025	.042	51.9	56.4	. .	. .	2.67	2.72
32	0.97	0.82	.035	.030	51.7	54.8	. .	. .	2.80	2.78
33	0.79	0.81	.028	.029	51.5	54.0	. .	. .	2.78	2.75
34	0.47	0.91	.018	.034	49.3	51.0	. .	. .	2.65	2.68
35	0.51	0.81	.020	.029	49.5	51.8	. .	. .	2.59	2.79
36	0.62	1.21	.022	.046	48.6	52.7	. .	. .	2.79	2.64
37	0.91	0.84	.035	.032	47.6	49.5	. .	. .	2.61	2.59
38	0.91	1.27	.031	.047	50.8	54.4	. .	. .	2.90	2.70
39	0.87	1.13	.031	.042	48.1	50.4	. .	. .	2.81	2.68
40	0.85	1.15	.032	.043	51.3	53.7	. .	. .	2.65	2.69
41	1.06	1.09	.042	.041	48.6	50.8	. .	. .	2.52	2.67
42	0.63	0.88	.024	.034	52.6	52.9	. .	. .	2.65	2.58
43	0.83	0.67	.031	.025	50.8	55.3	. .	. .	2.61	2.67
44	1.06	0.90	.039	.032	52.0	50.4	. .	. .	. .	. .
Av.	0.781	0.968	.0292	.0364	50.83	53.18	.00154	.00182	2.675	2.658

TESTS ON VACUUM CLEANERS

	No.	Revolutions per Minute.		Vacuum.		Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air.		Horse Power of Pump.	
		Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
111₀ { No dirt added; one-half rug with each sweeper	11	120	120	13.2	13.0	.25	.80	.0112	.0361	85.8	84.4	.0029	.0095	2.24	2.22
	15	121	121	12.7	12.1	.43	.56	.0209	.0276	82.0	82.8	.0053	.0068	2.06	2.03
	18	120	121	12.3	12.2	.27	.67	.0137	.0322	82.4	83.9	.0033	.0080	1.97	2.08
	27	120	123	12.5	11.9	.22	.58	.0110	.0296	82.4	83.5	.0027	.0070	2.00	1.96
		481	485	50.7	49.2	1.17	2.61	.0568	.1255	332.6	334.6	.0142	.0313	8.27	8.29
	Average per minute	120.3	121.3	12.68	12.30	.293	.653	.0142	.0314	83.15	83.65	.000355	.000783	7.068	2.073
									Free air per minute,	48.00	49.40	.000610	.00132		

BOOK REVIEWS

Reinforced Concrete[1]

This little book, which unfortunately has been written by a graduate of the Institute, illustrates the danger of running into print without taking good advice. The author states that his object has been to produce a reference handbook adapted to the wants of the architect, engineer, and contractor; and that the treatment "has been carried out along well-known formulæ based on the theory of elasticity, but modified by the usual assumptions, . . . not upon empirical formulæ based upon experiments," and he hopes that the volume will "tend to do away with the use of some of the empirical formulæ and rule-of-thumb methods." Unfortunately the book, with its tables and computations, is based upon entirely incorrect fundamental mechanical principles, which fact makes it not only valueless, but unsafe. Two illustrations will suffice to show the truth of this statement. In computing beams (pages 42, 43), the writer proceeds as follows: He takes the neutral axis at a certain point and then assumes the entire bending moment to be carried by the concrete beam, neglecting the portion below the rods and taking no account of the stress in the steel. This gives him for test beam No. 1 the compressive stress at the extreme top of the beam, 3,700 pounds per square inch. He then takes the same total bending moment and places it equal to the moment of the stress in the rods alone, taken about the neutral axis, with no allowance for the concrete, which gives him 55,000 pounds per square inch in the rods. He then assumes that the horizontal layer of concrete for a height equal to the diameter of the rods stretches the same as the rods, and that, therefore, the tensile stress in this concrete is 4,500 pounds per square inch! This method of computation, as any one familiar with the elements of the beam theory will see, is absurd.

His treatment of shear is equally erroneous. He first states that the vertical shearing force on any section is distributed over the entire section in such a way that the strain on the steel equals the strain on

[1] F. D. Warren: A Handbook of Reinforced Concrete for Architects, Engineers, and Contractors. New York: D. Van Nostrand, 1906. 271 pp.

the concrete. In other words, the stress of the concrete is uniform over the entire area of the concrete. He then says that the longitudinal shear varies from the neutral axis outward, diminishing from a maximum at the neutral axis to zero at the extreme fibers. He has evidently forgotten the principle that on any two planes at right angles to each other the shearing forces parallel to a third plane which is perpendicular to both have equal intensities. But, worse still, he then proceeds to compound these two unequal (!) shearing forces on different planes, and obtains a resultant shearing force on a plane making an angle of 61° with the vertical!

These two illustrations are quite sufficient to give an idea of the character of the book and of the unreliability of the author's reasoning. Further criticism or mention is unnecessary, for any one who makes such fundamental errors as the above is unworthy of further attention. Mr. Warren was taught the theory of beams, but he has evidently not mastered the first principles. It is very much to be regretted, for his own sake, that he should have rushed into print, and equally to be regretted that any publisher should have been advised to print the book.

GEORGE F. SWAIN.

THE POLARISCOPE[1]

IT will be well to quote from the preface of this book as follows:

"The immense importance of the sugar industry in world economics has forced the development of the polariscope into a sugar-testing instrument of high efficiency. Comparatively few practicing chemists are familiar with any other application of the useful laboratory tool.

"Many books have been written on commercial saccharimetry, but it is only by hunting through the whole mass of literature of analytic chemistry that occasional instances can be found of the application of the polariscope in general laboratory practice.

"Landolt's great work is the only one devoted to a complete treatment of the subject of polarimetry, but that is, in the main, a book for the physical chemist and trained investigator in pure science.

"Hence I have ventured to write a simple introductory treatise, not

[1] G. W. Rolfe: The Polariscope in the Chemical Laboratory. An Introduction to Polarimetry and Related Methods. New York: Macmillan, 1905. 7 + 320 pp., 37 il., tables, 12mo.

a complete manual of polarimetry by any means, but one explaining in an elementary way fundamental principles and their application in general laboratory practice.

"Naturally, I have devoted much space to methods in use in sugar manufacture, but have also described those used in brewing, the starch industries, and food and drug analysis as well. It has seemed best to introduce outlines of some technical processes and factory methods of chemical control to make the subject clearer. I have also overstepped the strict bounds of polarimetry to explain methods obviously accessory to many determinations.

"A sketch of the use of the polariscope in pure science is given in view of the great possibilities of the instrument in that field."

In this preface the author has well stated what his book is intended to cover.

The subjects of "The Polariscope," "The Saccharimeter," and "Accuracy of Saccharimeter Measurements" have been very carefully and scientifically considered.

The technical information given in these various chapters does not differ materially from what has been presented in other books, save in the original manner in which it is brought out.

The subjects, however, of the following chapters — "Notes Applying to Special Instruments," "Polarization of Cane Sugar — General Commercial Methods," "Sugarhouse and Refinery Methods," "Starch and Starch Products," "Miscellaneous Saccharine Products" — are handled in a manner only possible by one who has had considerable experience in technical and industrial work.

There is much information in these chapters which has never before been presented in any of the works on sugar, and is given by the author as the result of years of experience in technical and industrial work. Many of the difficulties which confront a technical chemist in work with the polariscope and saccharimeter, and which have never been alluded to in any other works, are discussed at some length, and it is possible for one with a technical training, but without experience with these instruments, to become thoroughly experienced in their use if he but follow closely the suggestions as given by the author.

The tables, which occupy a number of pages, have been selected with great care for the use of sugar and starch chemists, and form a valuable part of the book.

The book is one which can be heartily recommended to the technical

men who are obliged to use the polariscope or saccharimeter and who have not had a thorough, practical experience with them, and should be welcomed as a distinct addition to sugar literature, showing much original thought. L. W. P.

A Text-Book on Electric Railways[1]

This book is written as a text-book for the use of college students and as a reference book for engineers. Unfortunately, however, it does not seem to meet the needs of either class of readers. As a text-book it fails in that the subjects treated are largely those which are seldom discussed in the classroom; on the other hand, some of the subjects discussed are so elementary in character that they should be understood by the students before they begin to study the railway problem. As a reference book it fails in that it treats subjects which are well understood by engineers.

The book deals with railway motors, both those using direct and those using alternating currents, and it treats also of controllers, brakes and braking, car bodies, trucks, and minor details. The chapters dealing with units, instruments, recording apparatus, and curve plotting are incomplete, however, and lacking in the details that would give them value either to the student or to the engineer.

The chapter dealing with train performance is very good so far as it goes, but for students lacks much in regard to details which will need to be supplied by the lecturer.

In regard to controllers and also in dealing with brakes and braking we miss the details of operation, and the diagrams furnished are too small for practical use. The troubles of controllers are of considerable importance both to the student and the engineer, and it is unfortunate that the notes on this subject are not more extended.

In its entirety the book makes very good reading for a man who wishes to obtain a superficial idea of the method of planning an electric railway and some information as to the operation of the component parts of electric cars. But much of the book is elementary, and it is not likely to be found useful by either the student or the engineer who

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[1] S. W. Ashe and J. D. Keiley: Electric Railways Theoretically and Practically Treated. New York: Van Nostrand, 1905. 284 pp., 172 il., 6 pl., 12mo.

wishes to go deeply into matters of construction and operation of electric railways.

HENRY D. JACKSON.

NOTES ON ELECTRO–CHEMISTRY[1]

THE object of this work is, as stated in the preface, "to offer a general survey of the subject, to serve as an introduction to its study, and to aid in the securing of a proper understanding and appreciation of the work along individual lines."

Chapters I and II are devoted to very general subjects. Chapter I deals with inductive and deductive reasoning, the laws of the conservation of mass and of energy, and the C. G. S. system of units; while Chapter II gives a historical sketch of the growth of the knowledge of electricity from the earliest times down to radio-activity, and explains the units used in electrical measurements.

Chapter III, treating of electro-chemistry from a historical standpoint, and Chapter IV, on "Electrolytic Dissociation," are exceedingly brief. Electromotive force, for instance, is disposed of in a page and a half. This fact alone shows that the treatment of this subject must be inadequate to any purpose whatever.

Chapter V, on "Electro-Analysis," deals only with the principles underlying this subject, omitting all specific directions for carrying out the determination of any one element. The presentation cannot be said to be perspicuous, and is not always correct; for instance, on page 75 where the resistance of a cell is computed and incorrectly called the "reverse electromotive force."

Chapter VI, on "Electrotechnology," includes short accounts of metal refining, electroplating, the production of chlorine and alkali hydrates, and electric furnace products.

At the heading of each chapter is a bibliography of works dealing with the subject treated in that chapter.

This work could be of little use as an introduction to theoretical electro-chemistry, but it does point out the principal industrial applications of this science, and to this extent could be a guide to further reading.

M. DEK. THOMPSON.

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[1] Notes on Electro-Chemistry. By F. G. Wiechmann. New York: McGraw Publishing Co., 1906. ix + 145 pp.